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14. ABSTRACT
A Futures Conference was held in accordance with the directions of the Joint Service Small Arms Program (JSSAP) from 17-19 November 2009, at the Battelle Memorial Institute in Columbus, OH. The conference attendees were recruited from Battelle staff and primarily JSSAP personnel. The participants were broken into three groups under the guidance of a group leader who had small arms expertise.

The areas for discussion were:
• Energy: Supplying power for the warfighter's individual weapon system to reduce weight and alleviate resupply/logistics issues. Discussions were encouraged on better energy management methods including generation and conservation.
• Target Engagement: Improving the warfighter's ability to engage the target. This includes better sighting, the ability to mass fire, and engaging Beyond Line of Sight (BLOS) and Non Line of Sight (NLOS) targets.
• Target Effectiveness: Improving the effectiveness of any ordnance delivered on the target.

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Final Report: Futures Meeting November 2009

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Joint Service Small Arms Program
Armament Research, Development and Engineering Center
Picatinny Arsenal

Performed Under Contract No. W911NF-07-D-0001/DO 0052/TCN 07077

Executive Summary

A Futures Conference was held in accordance with the directions of the Joint Service Small Arms Program (JSSAP) from November 17 - 19, 2009, at the Battelle Memorial Institute in Columbus, OH. The conference attendees were recruited from Battelle staff and primarily JSSAP personnel. The participants were broken into three groups under the guidance of a group leader who had small arms expertise. The proceedings were under the direction of Mr. Larry Ostuni, a professional facilitator.

JSSAP specified certain areas for discussion. These areas were:

- **Energy:** Supplying power for the warfighter's individual weapon system to reduce weight and alleviate resupply/logistics issues. Discussions were encouraged on better energy management methods including generation and conservation.
- **Target Engagement**: Improving the warfighter's ability to engage the target. This includes better sighting, the ability to mass fire, and engaging Beyond Line of Sight (BLOS) and Non Line of Sight (NLOS) targets.
- **Target Effectiveness**: Improving the effectiveness of any ordnance delivered on the target.

The session began with the groups defining an *ideal* small arm and articulating the barriers to achieving the ideal small arm. These barriers included limitations on the current technology as well as softer issues related to the warfighter's perception of the weapon and difficulties encountered while in combat.

The groups began to define possible solutions to overcome the articulated barriers and to develop a notional time line for investment to address the challenges and develop the needed technologies. The groups developed seven such ideas. The seven concepts were categorized with respect to the appropriate topic area of Energy Usage, Target Engagement, and Target Effectiveness. The following table summarizes the concepts, a brief description, the timeframe for development, and a recommendation for development.

Topic Area	Solution Title	Description	Timeframe	Recommendation
Energy Usage	(None given)	To demonstrate the ability to collect / transmit 2-4 watts from the soldier to the weapon; to benchmark the technology; to quantify the benefits, needs, requirements, impacts and trade-offs.	2012 to 2017	Recommend for Development
Target Engagement	(None given)	Make the weapon scope a fully functional display and computing device to heighten warfighter's situational awareness.	2012 to 2010	Recommend for Development
Target Engagement	SPIDER integrated sensor system	SPIDER integrated sensor system for situational awareness sent to a scope with markers for friend, foe or unknown in the view as the weapon is panned (day/night, all weather) with targets in defilade or BLOS.	2012 to 2014	Not Recommend
Target Engagement	Big Fish	Launchable video camera connected to warfighter via fiber optic cable.	2012 to 2014	Recommend for Development
Target Engagement	Scalable non-lethal to lethal	Several possible directed energy weapons were considered – laser, microwave, acoustic, vortex ring, and plasma.	No Response	Not Recommend
Target Effectiveness	Door breaching	Remotely (15-75M away from the target) breech man-sized holes in walls (i.e., reinforced concrete) and doors from a small arms platform.	2012 to 2014	Recommend for Development
Target Engagement and Target Effectiveness	(None given)	Defeat the soldier of the future who is similarly armed, equipped and supported.	2012 to 2014	Not Recommend

Table of Contents

Executive Summary 2
Background of Effort 5
Workshop Organization 6
Workshop Agenda 7
Day 1 7
Group A: Small Arms 9
Group B: Recent Developments 11
Group C: Brainstorming 13
Plenary Session: Infinite Ammunition & Fire and Forget 14
Group A: Deep Dive Facts 15
Group B: Deep Dive Facts 16
Group C: Deep Dive Facts 17
Afternoon: Facts & Technologies 18
Days 2 — 3 20
Group A: Technology 20
Group B: Situational Awareness 24
Group C: Fire Control 29
Proposed Solutions and Development Timeframes 31
I. Energy Usage 32
II. Target Engagement 39
III. Target Effectiveness 53
Conclusion 64
Appendix A – List of Participants 66

Tables

Table 1 - Participants By Group 6
Table 2 – Facts Given Votes 18
Table 3 - Conventional Weapons vs. The Star Trek Phaser 22
Table 4 - Directed Energy Weapons 23
Table 5 - Summary of Workgroup Ideas 31
Table 6 - Summary of Recommendations 64

Background of Effort

The Joint Service Small Arms Program (JSSAP) has conducted several *Futures Conferences* over the last two decades. The purpose of these Futures meetings was succinctly stated by Bernard Tullington, the organizer of the first event held in 1986:

…provide a forum conducive to 'free thinking' in order to capture the thoughts and ideas of imaginative and creative people not necessarily prejudiced with current or past weapons development. [1]

Overall, the objective was to identify:

…alternative candidate futuristic weapons systems that would offer high-performance payoff.

The latest effort began in 2008 and was held as two separate events. The first event was attended primarily by science fiction writers. Their task was to generate novel concepts for new small arms research. The writers were not given any guidance as to specific areas to concentrate their efforts, but were allowed to freely discuss any ideas. In all, over 100 concepts were generated. The second event evaluated the feasibility and applicability of the concepts and was attended by representatives from industry, academia, and Department of Defense (DoD) civilians and active duty military. Although a number of interesting ideas were generated, further review showed that many had already seen significant development.

Thus, a third event was held in November 2009. The 2009 event was conducted differently than the 2008 effort. Instead of a free forum, discussions were focused in three specific areas of interest to JSSAP:

- **Energy:** Supplying power for the warfighter's individual weapon system to reduce weight and alleviate resupply/logistics issues. Discussions were encouraged on better energy management methods including generation and conservation.
- **Target Engagement**: Improving the warfighter's ability to engage the target. This includes better sighting, the ability to mass fire, and engaging Beyond Line of Sight (BLOS) and Non Line of Sight (NLOS) targets.
- **Target Effectiveness**: Improving the effectiveness of any ordnance delivered on the target.

Participants had expertise relevant to the three areas noted; however, it was not a prerequisite to have expertise in small arms. Attendees were from Battelle Memorial Institute, JSSAP and the Munitions Engineering and Technology Center (METC). A listing of these personnel is in Appendix B.

[1] B. Tullington and K. Guess, Summary Report on Future Alternative Weapons Concepts Workshop, JSSAP 9 (Task 2), Contract No. DAAH01-84-D-005, April 1986. pg 1-1.

Larry Ostuni, a professional facilitator from WisEngineering, Dover, NJ directed the discussions. Mr. Ostuni has a long involvement with small arms and the JSSAP office as well as facilitating the 2008 Futures effort. Mr. Ostuni divided the participants into three separate groups (see Table 1, below). Each group was led by someone with significant small arms background and experience.

Table 1 - Participants By Group

Group Designation	Group Leader	Participants
A	John Appel, Consultant	Jeff Carpenter, Battelle John Clay, Battelle Erik Edwards, Battelle Bradley Glenn, Battelle Don Lewis, Battelle Ralph Mazeski, ARDEC
B	Stan Goddard, Consultant	Joel Goldman, JSSAP John Edwards, JSSAP Darren Krasny, Battelle Chuck Pollock, Battelle Andy Valentine, Battelle
C	Vern Shisler, Consultant	Bart Halpern, JSSAP Charles Holmes, Battelle Anthony "AJ" Kuhlman, Battelle Lee Oesterling, Battelle Keith Zurlo, Battelle Larry House, Battelle
Larry Ostuni, facilitator		

This report discusses the meeting and presents the results. All sessions were audio recorded to document the discussions. In addition, an independent assessment of the technical state of the ideas generated is made.

Workshop Organization

The groups operated separately to discuss the three identified interest areas. Periodically the attendees would gather to brief and exchange ideas to encourage fresh perspectives from other people as much as possible. Additionally, the representatives from JSSAP freely moved among all groups.

Workshop Agenda

Day 1 -

Morning

- Introductory remarks
- JSSAP overview presentation (Joel Goldman)
- Working groups – What is the ideal firearm?
- Presentation of results
- DOD small arms capabilities assessment (John Edwards)
  Working groups – Fact finding: What are the barriers to results?

Afternoon

- The groups freely discussed issues pertinent to small arms and how to solve these problems
- The primary issues the groups addressed were situational awareness and keeping up with technology

Day 2 –

Morning

- Current small arms fire control efforts presentation (John Edwards)
- Continuation of previous day discussions

Afternoon

- Continuation of discussions

Day 3 –

Morning

- Continuation of previous day's discussions
- Conclusion

DAY 1

After introductory comments by Mr. Ostuni, Mr. Joel Goldman gave an overview of JSSAP to the attendees. In the beginning of his talk Mr. Goldman noted the seriousness of the JSSAP mission:

> *We're not making toasters. When toasters fail, it is not a big problem. When weapons fail, the results can be catastrophic.*

His talk covered several key points:

- Who is JSSAP? Who is involved?
- Strategic objectives as an organization
- How programs are put together
- How JSSAP collaborates with the armed services on a one-to-one basis and jointly.

Who is JSSAP? Who is involved? JSSAP is *…a chartered joint-centric activity providing small arms technology and requirements harmonization for all the armed services.* The JSSAP office provides intensive management of the DoD small arms technical base. This includes the harmonization of requirements across the armed services so weapons can go through the process of approval, manufacturing and deployment jointly. Synchronizing this outcome is a challenge as budget cycles differ for each individual service.

Mr. Goldman indicated that the purpose of this meeting was to assist in formulating mid- to long- range plans and strategies. Currently, this is envisioned as starting in the time range of 2012 to 2020.

In fielding a system, JSSAP harmonizes the requirements, develops the technology and then transitions the technology primarily to the program managers in the Army, with the Marine Corp as a secondary transition target. JSSAP also is engaged with the North Atlantic Treaty organization (NATO) and other international organizations as far as possible.

Mr. Goldman then spoke about how JSSAP interacts with all branches of the armed services. Representatives of these services form a board that meets semi-annually to review JSSAP activities and exchange information. Mr. Goldman spoke about the current members from the individual service branches.

Strategic objectives as an organization. Mr. Goldman noted several areas:

- <u>Awareness campaign</u>: Raise the level of awareness in DoD of who JSSAP is and what its role is.
- <u>Lightweight small arms technology</u>: This has been a JSSAP lead program for many years. The goal is to establish an official capabilities document that can be transitioned to a development document that can be transitioned to engineering and manufacturing development.
- <u>Joint Small Arms Capabilities Assessment and Joint Service Small Arms Master Plan</u>: Mr. Goldman described these as *…the foundations of the (JSSAP) program*. The Capabilities Assessment was a *…full scale, joint capabilities integration and development system.* JSSAP developed a new master plan by considering what is available and where the shortfalls in the current technologies are.

Mr. Goldman then followed with some examples of support given to the individual services.

Overall, for small arms development, Mr. Goldman noted that the goals for weapons should be:

- As light weight as possible
- Have as many common parts as possible
- Be as effective as possible.

Mr. Goldman concluded with how JSSAP achieves these goals.

Mr. Ostuni followed this discussion with a brief talk on creativity and expertise. He noted that experts tend to look at the world through the context of their respective expertise, and that the easiest way to break this connection is to interact with other experts. After a brief creativity exercise, Mr. Ostuni broke the groups into the teams noted in Table 1, and challenged the groups to formulate their vision of an *…ideal small arms system*. He noted that they had not been briefed on any specific requirements, and noted that there are two parts of this discussion; namely, there are *wishes*, and *why can't I do it now?*

The group discussions are summarized below. It is interesting to note that while the groups functioned independently, common themes emerged.

Group A: Small Arms

Mr. Appel began with an overview of small arms. Mr. Appel divided small arms into two categories; namely, personal or individual weapons and crew served weapons. Individual weapons are carried by the warfighter and can *…be operated without help*. Examples of these are pistols, sniper rifles or carbines. These weapons serve as the primary means for the warfighter to conduct the mission and to protect him or herself. Crew served weapons are carried and operated by two warfighters and include heavier weapons like machine guns and mortars. Mr. Appel focused the group on the warfighter's individual weapon.

Mr. Appel noted several issues with current individual weapons. He noted that weapon weight is an issue. Although the weight of the basic carbine is not excessive, the addition of ammunition and a weapon sights add significantly to the overall weight of the basic weapon.

Mr. Appel suggested the Star Trek *Phaser* as an ideal weapon model. The Phaser was a pistol-sized directed energy weapon that could be selectively lethal or non-lethal and had a virtually unlimited power supply (*infinite ammunition*). Other group members noted that the Phaser never appeared to fail despite being in a variety of environments as well as being light weight.

The Phaser concept was carried further — allowing the beam to cover either a large or narrow area. Another suggestion was to have variable range on the weapon, so that the same weapon and ammunition type could be applied to different situations with minimal risk of collateral damage or by-stander injury and death. The warfighters should be able to attack without exposing themselves to adversary fire; moreover, soldiers should have a weapon that is self aiming and stabilizing so effective fire while moving is possible.

One suggestion included a mentally controlled weapon that could respond to the shooter's thoughts by seeking and attacking the target, even a non line of sight target (one group member suggested *…marrying the Tricoder [a hand held universal sensing device] with the Phaser*).

The group discussed coordinated fires or group fire control. In this scenario, which was posed as an asymmetric or irregular combat situation, each warfighter has the ability to obtain specific coordinates for individual targets. The target is then attacked by whomever has the best shot. This scenario requires each member of the force to have GPS and laser range finding capability (although not mentioned, the target heading from each warfighter would have to be included). All warfighters are linked via a local data network that automatically updates all information. As Mr. Appel noted,

> *…pretty soon you have a situational awareness building up, where I know where the fighters are and I can start picking them off, versus just being stuck there and not knowing where to shoot or what to do. This would be a whole lot better than what is being done today.*

Mr. Appel also noted that soldiers are under a tremendous weight burden, to the point that is injurious. However, conventional kinetic weapons also have weight boundaries in that recoil can become unmanageable if the weapon is too light. Weight reduction must come from other areas.

Mr. Lewis also brought up the weapon being *non-detectable*, which is a reference to reducing the weapon signature. Mr. Appel noted that there may be utility to making the signature variable, in that the signature sometimes adds a warning or physiological factor to the weapon (similar to the *Panic Grenade* in the 2008 conference).

The group also considered placing a combat awareness sensor on the weapon, so that if supporting fire is needed (mortar fire or rockets for instance) the weapon automatically calls for it. This was termed *target hand-off capable*. Mr. Appel noted that this was considered as part of the Army *Rapid Force Projection Initiative (RFPI)*, described as:

> *RFPI is a sensor-weapons-Command, Control, Communications, Computers, & Intelligence (C4I) concept that allows light forces to fight the majority of the battle out of contact using non-line-of-sight killers.*
>
> *RFPI also demonstrates real time targeting from forward sensors to standoff killer weapon systems with the capability to engage high value targets, including heavy armor, beyond traditional direct fire range. Target transfer is facilitated by tactical digital data transfer systems being developed as part of the U.S. Army Battle Command*

System (ABCS). This synchronization of dispersed forces results in increased force lethality and survivability.[2]

The group also delineated technology boundaries for the realization of a Phaser like weapon. These included:

- Power generation and storage, enabling a *deep magazine*.
- Phaser lethality technology is not yet developed, assumed to be different than a laser weapon. It was thought that the power density of the projected beam is a key factor in the lethality mechanism.
- The information sharing network does not yet exist, although it is under development.
- Control components likely too large for a pistol type device. This includes the computing power as well as any kinematic device to stabilize the weapon.
- Information processing algorithms are not yet available.
- The legal aspects of the Phaser are not known. The group noted that the difference between lethal and non-lethal may not be discrete but a continuum, so a non-lethal weapon may permanently disable someone.
- Will the weapon power source cause a hazard to the user?
- The weapon should have a long functional life.

Group B: Recent Developments

Mr. Goddard began his session with a review of recent developments that he considered as new challenges. His initial example focused on robotics, foreseeing that another country could launch surveillance and target designation unmanned aerial vehicle (UAV). Mr. Goddard believed that the new small arms weapon should be able to defeat this new development; specifically:

Where the UAV is? Am I being surveilled? Am I a target? What can I do about it?

Mr. Goddard also noted that state-of-the-art military grade equipment is available from other nations, and that the technology advantage the US enjoys is diminishing, even in combat with insurgents (Mr. Goddard gave an example of Chinese helmets that he thought were … *better than what our guys have got in some places of the world).*

[2] P.J. Deason and G.B. Tackett, *Rapid Force Projection Initiative Advanced Concept Technology Demonstration (RFPI ACTD) – The Experimental Path*, http://www.galaxy.gmu.edu/ACAS/ACAS00-02/ACAS02/DeasonPaul/DeasonPaul.paper1998.pdf (retrieved December 7, 2009).

Mr. Goddard asked about defeating a UAV surveillance system. His discussion centered around two questions:

- How do warfighters detect it? Warfighters need detection that will work in all conditions.
- How do we stop it? How do we attack it with a small arms weapon?

Dr. Krasny observed UAVs are a US development, and that it should be possible to have counter UAV systems that can seek and destroy adversary UAVs. He further noted that unmanned ground vehicles (UGV) are also possible. Overall, he envisioned that there may be groups of friendly force ground and aerial autonomous UAVs that seek and destroy enemy unmanned vehicles as part of their mission.

Mr. Goddard focused on disabling or destroying the enemy unmanned vehicle. Destroying the enemy UAV is one option, but this may not be in the warfighter's capability or even in the warfighter's best interest. Indeed, the warfighter's objective may be to remain invisible. Instead, a better option would be to negate the effectiveness of its surveillance capability as this could maintain the warfighter's invisibility. Suggestions for negating the surveillance capabilities of the enemy UAV/UGV included:

- *Using obscurants* – This includes smoke or some kind of chemical that cannot be penetrated by enemy UAV/UGV surveillance mechanism or else diverts its attention away from the friendly warfighters.
- *Disabling the sensing electronics* – The methods suggested included using an electromagnetic pulse (EMP) or a laser to permanently blind optics. Mr. Valentine suggested, however, that these overt measures are revealing, defeating the purpose of disabling the UAV/UGV as opposed to destroying it.
- *Blinding the UAV/UGV* – Cloud the optics using glue mixed with opaque particles.
- *Deception* – Spoofing the surveillance system so it doesn't recognize or detect our forces.
- *Distracting the drone* – If the system is autonomous, give a spoof target that it finds more attractive.
- *Confuse the basic intelligence control of the UAV/UGV* – Robots like these are autonomous. The challenge of autonomy is how well the robot performs without human intervention. Isolating the robotic UAV/UGV from communications may have the system go into a "safe" mode that stops it from operating.
- *Destroying the drone* – Give the warfighter a scaled down version of the Stinger man portable air defense system (MANPADS).

Mr. Goldman asked if it would be possible to assess the UAV/UGV capabilities from a distance, so the most efficient way of defeating it can be employed. Mr. Goddard further suggested equipping the warfighters with a computerized UAV/UGV capability that would tell the warfighter the best way to counter the threat once it is known.

The discussion turned to ways of countering the threats. These included:

- *Fooling the sensor*. Mr. Valentine believed that convincing the sensor that it was looking at something other than the friendly force. This included intercepting the communications from the robot and substituting images that do not reveal friendly forces.
- *Camouflage friendly forces*. This could include using native garb, disguising weapons as sticks, and projecting images or having inflatable versions of common domestic livestock.

The group also discussed technical limits. Mr. Goddard suggested that any weapon needs to be *small*. Miniaturization will be a key.

Group C: Brainstorming

The group attacked the challenge question by *brainstorming* ideas that were then discussed. Small arms were defined as:

> *…weapons that individual soldiers carry. So, it would be things like pistols, and more likely rifles and machine guns and submachine guns. …it also includes crew served weapons, a big machine gun… that two guys have to carry parts of it and emplace it.*

Mr. Shisler then began by noting requirements that the current user would likely be looking for in an ideal weapon system. These attributes include:

- As light weight as possible – preferably a non-noticeable weight
- Have very long effective range, possibly on the order of miles
- Possess an infinite ammunition supply

Other attributes suggested by the group members included:

- 100% reliability – the weapon should never break or fail
- Common operations/functionality for weapon control – trigger pull, safety operation and loading should be the same on all weapons systems of a common type
- Extremely accurate
- Easy maintenance
- Weapon sights that are useful for all conditions (night, thermal, weather)
- Common sights for all weapon platforms. A potential difficulty is that the sights must be zeroed to their attached weapon. Pre-zeroed or auto-zeroed scopes would be required.
- Sighting without the warfighter being exposed to fire. Ideally, the connection between the weapon and the warfighter should be wireless to prevent issues with having a tether between a weapon and the warfighter.

- Identify friend or foe electronically; this may include situational awareness that identifies potential targets
- Use commercially available sources whenever possible
- Single power source for all weapon systems (scope, laser designator)
- Compact weapon with extreme range accuracy/long range precision
- Fire and forget ammunition; ammunition that can seek a target although it is out of visual range. The projectile could use some kind of image recognition technology.
- The ability to selectively shoot through walls
- Long range wind sensor (similar to White Feather)
- DNA seeking bullets
- Neutralize threat propellants
- Weapons that only fire when they are handled by an authorized person. Can be biometric.
- Rapid target engagement
- Weapon recognizes when to switch between semi-automatic and automatic operations
- One-hit/one-kill bullets. The projectile would not have to hit a critical organ to kill. May be partly a perception/training issue.
- Scalable effects between lethal and non-lethal. This should be a function of the weapon and not of the type of ammunition being used.
- Weapons that use electromagnetic pulses

The group then discussed, in general terms, implementing coordinated fires among members of a group, as referred to as massed fires. Ideally, the target should appear as an indicator in the sights of all warfighters. Minimally, this would require all warfighters to be networked and having some kind of means to account for differing points of view of a dispersed group of warfighters.

Plenary Session: Infinite Ammunition & Fire and Forget

After the groups reconvened in the main conference area, Mr. Ostuni made a few comments on the creative process. Among other comments, he indicated that one way to restart a stalled creative process is to simply combine two dissimilar ideas at random and look at the possibilities. He chose *infinite ammunition* and *fire and forget* as an example. Although dissimilar on the surface, Mr. Ostuni noted that having true fire and forget ammunition would result in decreased ammunition usage, hence leading to a much deeper magazine. Similarly, if the shooter is a target designator, then the shooter's ammunition becomes infinite, since others are using their ammunition supply to attack a target.

Mr. Edwards briefed the audience on the DoD small arms capabilities assessments done over the last few years. The process is formally referred to as the Joint Capabilities Integration and Development System (JCIDS). JCIDS looks at defining new systems that address capabilities gaps. The personnel who perform these assessments represent all branches of the armed services and they are focused on the needs of the warfighter.

The evaluation is conducted as a three part process:

1) Functional area analysis – The analysis identifies operational task, conditions, and standards needed to accomplish military objectives.[3] Small arms are categorized as belonging to force application and force protection.

2) Functional needs analysis - Assess ability of current and programmed capabilities to accomplish the tasks.

3) Functional solution analysis - Operational based assessment of Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF) approaches to solving capability gaps.

Mr. Ostuni directed the group to begin *…going deeper into the problem.* He directed the groups to generate facts relevant to small arms. He challenged the groups to develop 30 to 50 facts each. The groups were directed to not discuss any fact in depth, but to simply record each idea and then move on to the next. These are delineated below without editing:

Group A: Deep Dive Facts

- 80% of engagements are less than 300 meters range; Afghanistan has more engagements over 300 meters, however
- Solutions may not be material; Non-material solutions are faster to implement
- Training is essential and perishable
- Perception of needs vary; small arms are a very emotional subject
- Best solution is scenario dependent – urban solutions will differ from rural solutions for example
- Longer range weapons and ammunition are heavier
- Personnel have different abilities
- Fire control is a significant gap
- Warfighters are overburdened – ammunition is a significant weight contributor. Replacing the brass casing with either a polymer or using caseless ammunition will alleviate this.
- Weapon effect probability = (Probability of hit) x (Probability of incapacitation). Probability of hit is composed of four factors; namely, the warfighter, his training, the weapon being used and the fire control optic. Probability of incapacitation is a function of the ammunition (caliber, behavior upon entering the body).

[3] Joint Staff, J-8 Capabilities and Acquisition Division, JCIDS Overview, http://www.dodccrp.org/files/02_20_04_JCIDS.ppt, retrieved June 22, 2010.

- The lethality of the bullet will depend on the bullet's caliber, velocity, plasticity and fragmentation once it penetrates the target
- Range is a function of the bullet, barrel length and propellant
- Tactical fire control requires communications between warfighters
- Logistical "tail" is not trivial
- Ammunition supply is still a concern; it is a logistics challenge
- Sustained rate of fire is limited by thermal properties of the barrel (viz., the ability to dissipate heat)
- Once a round is fired there is no longer any control of it
- Making technology available in a competitive environment is a challenge (*keeping the playing field level* as one participant put it)
- JSSAP has a 40/60 split between 6.2 and 6.3 level programs
- Significant changes are likely in the nanotechnology and computing/signal processing world

Group B: Deep Dive Facts

- Target is changing. Even in irregular/asymmetric combat, the enemy will likely be equipped with body armor. Current systems may not be adequate.
- Combat environment is changing from traditional
- Technology is moving fast
- Requirements are changing
- Lethality and capability of individual soldier needs to increase
- Weapons are too heavy
- Soldier's physical load is limited; there has been no progress in changing either the load or the soldier
- System complexity is increasing
- Young soldiers are more computer savvy; would prefer a control system that looked like a game system
- Learning styles are changing. More learning may be by doing as opposed by rote/manual.
- Need smarter munitions
- Kinetic Energy (*i.e.*, traditional bullet) systems have not evolved; cartridges are still composed of a casing, primer and propellant
- BLOS warfare needs improvement
- Basic combat skills are being lost (navigation, etc.)
- Susceptibility to power loss is great
- Small arms need to get smarter; no better than the warfighter shooting it.
- Identify fast moving technologies and take advantage
- Mental load on soldiers too great; need to reduce the information flow to the most essential
- Weapons need to be networked

- Weapons need to be more versatile
- Weapons need more standardization
- Communications are still a problem; need better reliability
- Soldiers need increased situational awareness
- The battlespace is 3-dimensional
- Industry products not robust
- Hard to identify friend from foe, or identify an insurgent enemy
- Less soldiers in the field today than 10 - 20 years ago

Group C: Deep Dive Facts

- Warfighters are stressed – This results in shooting errors
- Warfighters are frustrated in the amount of ammunition they can carry – they want limitless ammunition
- Soldiers are afraid to fire their weapons since they can be exposed to enemy fire
- Training improves accuracy
- Training improves efficiency
- One solution will not fit all needs
- Batteries have limited lifetimes
- Weapons jam/become non-functional
- Sights need to be zeroed
- Warfighters are individuals – they all perform differently as opposed to a tank or other weapon
- Weather affects engagement
- Weapons are heavy
- Lethality increases survivability
- One shot does not always kill
- Soldier can be influenced by factors out of his immediate control
- Soldiers prefer certain weapons over others – personal opinion counts
- Soldiers are difficult to model
- There are no certainties in battle, soldiers need to adapt to threat changes
- Soldiers always want to shoot farther with higher probabilities of hit with a lighter weapon
- EMP weapons are expensive to produce
- Money is not unlimited
- Combat identification is difficult
- Weapons can be stolen
- Rules of engagement can change. Collateral damage is a concern.
- Have to work within the Laws of Physics
- Time is always critical
- Information is perishable/time-sensitive

- Communications are not necessarily 100% secure
- Weapons break/malfunction
- Soldiers have limited physical endurance; fatigue affects aim and general effectiveness
- There are no teachers in the heat of battle; skills and training are perishable
- Mistakes cannot be tolerated
- Soldiers do not like to maintain weapons
- Soldiers die
- Protection limits mobility.

It is interesting to note that the groups independently duplicated some ideas. For example, several comments focused on the inherent limitations imposed by a human warfighter.

Afternoon: Facts & Technologies

Mr. Ostuni began the afternoon by discussing the facts generated by the individual groups. He then had the group list the technologies that are currently being driven or evolving faster.

- Wireless communications
- Batteries/power supplies
- Computing power
- DSP
- Antennas
- Materials

Mr. Ostuni began the afternoon by having the groups vote on the *facts* generated in the morning. The results were as follows:

Table 2 – Facts Given Votes

Facts	Votes
Technology evolving faster than government can acquire it	9
Must work within the laws of physics	8
Power sources are limited	7
Fire control is a fruitful area for improvement	6
Large aiming errors	5
Soldiers are overloaded	5
Bullets do not have brains	4
Effect depends on bullet and target	4
One shot does not always kill	4
Soldiers difficult to model	4
80% of engagements are under 300 meters	3
Affordability is a significant factor	3

Facts	Votes
Small arms is an emotionally charged subject	3
Soldiers are stressed	3
Soldiers do not like to do maintenance	3
Accuracy varies with individual	2
Collateral damage is a problem	2
Logistics are not trivial	2
One solution will not fit all needs	2
Personnel have different abilities	2
Protection limits mobility	2
Solution is environmentally dependent	2
Technology takes a very long time to get fielded	2
Time is critical	2
Weapons are not universal	2
Ammunition is heavy	1
Ammunition supply is a logistics challenge	1
Ask soldiers to do a lot	1
Communications can be intercepted by the enemy	1
Fear of exposure/risk	1
Information is critical and perishable	1
Information requirements change	1
Non-material solutions are faster to find	1
Probability of hit (P_H) is a function of soldier, training, weapon and optic	1
Skills and training are perishable	1
Soldiers are killed	1
Soldiers run out of ammunition	1
There are limits on physical effect on soldier	1
Things break	1
Training improves accuracy	1
Weapons jam	1
Weather affects engagement	1

Mr. Ostuni then charged each team to solve questions related to fire control, situational awareness and technology. The groups were instructed to focus on several criteria; namely, technology, costs, effectiveness and time to availability (specifically, within the 2012 – 2020 timeframe).

DAYS 2 — 3

The individual group discussions continued throughout the remainder of the conference and are summarized below.

Group A: Technology

Group A was charged with addressing how technology is evolving faster than the government can acquire it. Mr. Appel commented that progress on weapons is comparatively slow. He noted the experience with the M16 rifle, which was introduced during the Kennedy administration and is still in service in 2010. He further commented that M16 development has been directed at improving the fundamental design as opposed to introducing new features on the basic weapon (this excludes items like scopes, which attaches to a rail and the M203 grenade launcher which is on the M16 forearm). Additionally, a weapon is basically a closed architecture design and is not amendable to radical new technology insertions. Inserting new technologies would be facilitated if the weapon had an initial design that allowed for basic changes to be inserted.

Group A also discussed general issues on inserting new technology into the military. Mr. Appel noted that there are institutional reasons why new technology is not readily inserted into the military. Specifically, equipment in the military tends to be in lanes (for instance, artillery, armor, small arms, and so forth). Inserting new technology may require the technology to be across several lanes which does not readily happen. *Group A* further noted that JSSAP has some inherent limitations that prevent their rapid acquisition and insertion of technology. These limitations were thought to be primarily due to a comparatively limited budget and JSSAP's position in the Army organization.

Other improvements may not be feasible if it adds too much expense to a mass produced system. For instance, conventional rifle bullets are produced…*by the millions*. Adding an improvement like on-board guidance that raises the cost by only a few pennies per bullet will have a large financial impact.

The group initially found the question of constantly inserting new technology to be intractable, and refocused their efforts on a different question; namely, *in what ways can the government stay aware of new technology?* Solutions included: attending conferences and exhibitions, reading the literature, attending courses and holding competitions, performing studies, and issuing Requests for Information (RFI).

The group did focus on holding competitions similar to those that DARPA has sponsored, noting that DARPA had great success with their *Grand Challenges* in promoting technological development. A recent example is the autonomous robotic vehicle challenge. This not only makes the sponsoring agency aware of technology but also establishes a relationship with individual and institutional entities that are interested in this field. Mr. Ostuni suggested that the group develop a list of grand challenges, specifically addressing the areas of interest to small arms such as lethality.

The group began by further defining what the *Grand Challenges* should entail. They decided to focus on three main areas based on JSSAP stated needs: specifically *Fire control, Situational Awareness* and *Terminal effects*.

Fire Control Grand Challenges

The group began by establishing a baseline based on today's sight capability. Today's weapon sight typically presents a magnified view of the target and may provide some aiming aids. This includes night sight scopes. This also includes fused spectra scopes which merge several light regions into a single presentation to the warfighter. Terahertz and acoustic frequencies were also mentioned.

Mr. Appel noted that remote fire control applications for weapons require the target's range and bearing. He further noted that the scope must work in all environments – rain, snow, day, night, dusty, smoky and so forth.

The challenge would be to develop a scope that is lightweight and small to preserve the weapon center of gravity and reduce the weapon weight. The scope should also be capable of active (designating the target for another weapon) and passive sighting modes. In either mode, the scope must be capable of providing range and bearing to the target. This will at least require global positioning capabilities. In order to communicate, the sight must have the ability to directly link into the warfighter's communication network. The subject of power was also discussed. It was decided that a benchmark of 2 – 3 days per battery is reasonable.

Situational Awareness Grand Challenges

The group then considered *situational awareness*. Grand challenge attributes include self location as well as locating friends, enemies, and non-combatants/neutrals. *Change detection* was also suggested which could include time based tracking; in other words, if someone goes out of sight, the system could "replay" the tracked person's moves to the point the enemy disappeared. One member extended the scope of the device to be not only identifying others in the battlefield, but also for communicating future actions, either from a command side downward or from the individual warfighter upwards.

Terminal Effects Grand Challenges

Finally, a grand challenge for *terminal effects* was considered. Terminal effects were defined as what happens when the round reaches its target. They restricted the discussion to kinetic energy systems only because it was felt that directed energy weapons would not be practical before 2020.

Initial discussion was on a rifle launched Taser®-like device that was capable of a 300 meter range. Most current Taser devices are range limited since a wire is trailed back to the launcher to provide the electrical shock. It was noted that Battelle has done work on the energy dissipating material to prevent the round from penetrating the body.

A second concept was changing the way the round interacts with the target after the bullet left the weapon. The concept assumed the intended target was tagged by a laser. If the bullet hit the intended target, the bullet would retain its lethal characteristics. The bullet would be less than lethal if it hit an untagged target. This could reduce or eliminate fratricide and non-combatant fatalities, as well as providing variable lethality in the field. Mr. Appel noted that shaped charges can vary their effects through changing the way the explosives are initiated. In this instance, the bullet could retain its shape and size if it was meant to be lethal versus fragmenting if the bullet was designated non-lethal.

Mr. Lewis suggested *guided bullets*. Mr. Appel suggested that this should be employed for specialty weapons like sniper rifles due to the perceived costs. Mr. Appel also suggested giving bullets the ability to sense the target and modify actions based on this. For instance, the bullet could sense if the target was wearing body armor and adjust actions accordingly.

Mr. Appel continued the discussion on the Star Trek *Phaser* the next morning (November 18, 2009). The group was joined by Mr. Goldman and Mr. Mazeski. Mr. Appel began by setting a baseline of today's small arms so they would have something to compare against. This evolved into a comparison of today's small arm versus the Phaser as a result of Mr. Mazeki's inquiry of *what effects do you want?* This comparison is noted in

Table **3**.

Table 3 - Conventional Weapons vs. the Star Trek Phaser

Conventional weapon	Phaser
Effect is only kinetic energy	Large number of possible effects; could be directed energy, acoustic, or something not yet discovered
Lethal vs. non lethal is unpredictable. A bullet hitting bone or a dense organ could go anywhere and still be lethal.	Precise choice between lethal and non-lethal
Finite magazine	Magazine depends on how good the power supply is, and may depend on how the weapon is used (non lethal may use less power than lethal)
Weight is high	Must be comparable to current systems
Can only hit one target at a time	Beam can be narrow or wide depending on setting

Line of sight aiming (Note: Can use a ballistic trajectory)	Line of sight aiming and travel

Mr. Appel noted that the precise demarcation between lethal and non-lethal effects allows the weapon to be used in any environment; that is, it can be used to kill an enemy or maintain control of a crowd of non-combatants where non-lethal means must be used. The group then considered directed energy options due to its similarity to the implied operation of the Phaser. These options are shown in Table 4.

Table 4 - Directed Energy Weapons

Energy/Phenomena	Advantages	Disadvantages
Laser	Technology known and mature. Power output and hence effect can be customized. Precise; line of sight for aiming purposes.	Line of sight limited; cannot use a ballistic arc. Legal issues for eye safety and rules of war. Detectable. Low power conversion efficiency. Beam can be degraded over distance.
Microwave	Technology deployed (active denial system). Deep magazine; consumables are linked to power supply (fuel). Non-lethal effects are good. May be scalable between lethal and non-lethal.	Large aperture antennas required to focus and get the required energy density; difficult to focus on one person. Currently transported on a vehicle. Crew safety from emitted radiation may be an issue. Detectable. Line of sight only (although may reflect off some surfaces).
Acoustic	Technology deployed (Long Range Acoustic Device (LRAD)). May or may not be lethal (tied to the pressure generated at the target). May not be detectable without highly specialized equipment. May be able to cover a large area by widening or narrowing the emitted beam (adaptable beam width).	Tied to overpressure at the target. Time required to achieve effect may be on the order of several seconds. Systems may not be focused; large antenna aperture may be required. Not a precision weapon. Atmosphere may limit range and effects.

Energy/Phenomena	Advantages	Disadvantages
Vortex ring gun (ring of higher pressure air)	May be variable between lethal and non-lethal, although likely is non-lethal only (would likely cause a person to fall). Non-detectable; would require an optical system that would detect a change in optical index. May be rapid fire; refill of weapon speed of sound (air flow) limited.	Range likely limited to 100 meters. Precision is dictated by the size of the exit aperture and environment. Line of sight limited. May not be man portable since aperture size will dictate the size of the resulting ring, and in order to get the ring size to the point where it will affect a man, it will have to be at least that size.
X-rays	May have long range; not affected by the environment. May be lethal or non-lethal. May be able to readily penetrate materials (NLOS), although air may attenuate X-rays. Not likely to be environment affected. Can it be produced as a throwable weapon? Can it be something that can be dismounted?	Crew/warfighter safety issue. Diffraction issues may require large aperture. What is the Highest possible dose of X-rays that can be generated?
Gamma rays	Scalable between lethal and non lethal. Highly penetrating.	Long term effects on soldiers unknown. May have legal issues.

The group discussed briefly a weapon that generates a large pulse of electricity; in other words, man-made lightning. However, the group noted that this had been done.[4]

One aspect of directed energy weapons that Mr. Appel brought up was the possible vulnerability of these weapons to anti-electronic countermeasures like an electromagnetic radiation pulse (EMP). Indeed, in these situations the only weapons that could still operate are low technology ones like the M16 with iron or simple combat optic sights.

Industry already uses many of these directed energy forms for manufacturing and inspection purposes, so their physiological effects have been investigated and documented. Moreover, lasers, microwaves and acoustic devices are being weaponized, primarily as non-lethal devices.

[4] A company called Applied Energetics (formerly Ionatron) is the …*sole and exclusive developer of Laser Guided Energy ("LGE™") and Laser Induced Plasma Channel ("LIPC®") technologies. These revolutionary technologies can precisely transmit high voltage electrical charges by using an ultrashort pulse (USP) laser to create a conductive path in the atmosphere. This technique can deliver tailored weapon and countermeasure effects to targets with laser accuracy, and with manageable lethality to reduce the potential for inadvertent injury and collateral damage.* http://www.appliedenergetics.com/laser-guided-energy.asp (accessed August 4, 2010).

Group B: Situational Awareness

The group focused its initial discussions on *situational awareness* for the individual warfighter. The group began by trying to define what situational awareness entails. As stated by Mr. Valentine, it should be "*…information you want when you need it in a timely fashion*." The group believed that situational awareness is composed of:

- What is the objective?
- What is the terrain?
- Where are the friendly forces, the enemy forces, and the non-combatants (civilians)?
- Weather conditions?
- Supply and logistics – where are reinforcements, heavier weapons, medical assistance?
- Where are you relative to the terrain?

The group then centered their discussions on two key questions: How much information does the warfighter need? And how is the information best presented so the warfighter is able to comprehend it while still remaining focused on the battle?

In discussing the first question, Mr. Pollock noted that there are two types of information; namely, "…*there is information that is critical to the warfighter's survival and there is pure information*." Information critical to the warfighter's survival is dynamic and needs to be real time. Pure information may not even be needed by the lowest level warfighters but is required by the higher command levels. Mr. Goddard noted that information required by the warfighter includes when the area is about to come under support fire from heavier weapons so the warfighter can evacuate the area.

Mr. Goddard remarked that coordinating fires on the squad or platoon level should be considered. As he put it, when one warfighter starts firing at a target, all other warfighters tend to do so as well, leaving other targets unengaged as well as using a limited ammunition resource. Having the capability to engage less visible targets is beneficial.

The group then considered ways to present this information to the warfighter that minimizes distraction from what is going on in the battlefield. It was speculated that the amount of information would have to be tiered by a person's role in the battlefield. One participant brought up the *Information Dissemination Management – Tactical* program being conducted by the Army. This was a subscription based service, with the warfighter basically selecting what information feeds he needs from the command network. (Note: This is also referred to as the Warfighter Information Network - Tactical (WIN-T).[5])

[5] Program Executive Office Command and Control Communications Tactical, Project Manager Warfighter Information Network - Tactical (WIN-T), http://peoc3t.monmouth.army.mil/win_t/win_t.html (accessed July 8, 2010).

Mr. Goddard speculated that representing information as a series of symbols on an iPhone™ like device could facilitate this by letting the warfighter determine what would be needed at a given moment in time. Mr. Krasney suggested that the weapon fire control device display the information. Conceptually, the device would integrate information from a number of sensors, including those from other warfighters in the vicinity. Mr. Krasney noted that the user should be able to customize the display so that it is suited to the warfighter's comfort. Mr. Valentine noted that this is similar to *Blue Force Tracker*, which is a vehicle level system.

> *Blue Force Tracker is a digitized battle command information system that provides on-the-move, real-time, and near-real-time information to tactical combat, combat support, and combat service support (CSS) leaders and Soldiers. Blue Force Tracker is a key component of the Army Battle Command System (ABCS) and seamlessly integrates with the other components of ABCS at the brigade level and below. Blue Force Tracker supports situational awareness down to the Soldier and platform level across all battlefield functional areas and echelons. Blue Force Tracker also allows brigade- and battalion-level commanders to exercise command when they are away from their tactical operations centers (TOCs) because they can interface with subordinate commanders and leaders who also are equipped with Blue Force Tracker.*[6]

Other discussions concentrated on the device form. For instance, the group considered what would happen if the information display (either the weapon scope or a heads up display on the warfighter helmet) had to receive the information from a separate device. A wired connection was deemed undesirable since it would possibly interfere with the warfighter's movement; wireless connections on the other hand produce a signature that could be exploited by an adversary.

The group did note that the device had to be dynamic and not command driven. In other words, the device must update the situation automatically as opposed to the warfighter querying the system. The information the warfighter receives must be filtered to be relevant and clear. The group apparently felt that location in the battlespace could be used for filtering purposes. Currently used technology includes the Enhanced Position Location Reporting System (EPLRS). (Note: Although these are the embodiment of what is being sought by the group, the units are comparatively large and at 26 pounds are too heavy for individual warfighter use.[7] Alternatively, companies like Garmin produce small GPS/radio combination systems that allow for automatic position updating, so such a unit for the individual warfighter is feasible.) An additional concern was that the radio network would be unable to support the likely number of required users.

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[6] Major James E.P. Miller, *Improving Situational Awareness in the Division Logistics Command Post*, Army Logistician, 38 (4), July-August 2006, http://www.almc.army.mil/alog/issues/JulAug06/sit_aware_divlog.html (retrieved June 23, 2010)

[7] Marine Corps Tactical Systems Support Activity, EPLRS Fact Sheet, http://www.mctssa.usmc.mil/documents/datasheets/EPLRS%20Fact%20Sheet%20Aug%2008.pdf (retrieved July 14, 2010).

Group B also discussed what constitutes *seeing the target*. Specifically, the warfighter observes his immediate environment and draws conclusions from what is seen and heard. It was noted that for a target in defilade, the warfighter may not clearly see the adversary but may draw conclusions from perceived actions from that area. By analogy, using sensors that are remotely placed can achieve the same results while greatly extending the range of the warfighter's information gathering. Data may come from a series of sensors as opposed to a single visual sensor. Likely advantages to using sensed data include reduced sensor power consumption, small sensor size, and reduced data transmission needs.

As Mr. Goddard noted, however, the role of JSSAP restricts these sensors to something that is either fired from or attached to the warfighter's weapon.

Mr. Valentine suggested a sensor dispenser based on a 40 mm grenade launcher form. These can be low velocity, alleviating the acceleration shock on the sensor package. The dispenser itself disperses sensors that are aspirin sized from locations on the sensor's circumference. The phenomena the individual sensors detect would vary. Some could detect magnetic disturbances, suggesting that metal from a rifle or improvised explosive device (IED) is present; others could sense vibrations and still others heat. The sensors would not use battery power, but instead use a small capacitor that would provide sufficient power for a limited amount of time while alleviating shelf life issues.

The center core of the launched dispenser provides communications and a means of charging the capacitors in the sensors. The group believed that the sensor dispenser should have a piezoelectric device that would harvest energy from the sudden acceleration of firing the round. Apparently, the thought was that the sensors would communicate to the center core and the core would relay the information back to the warfighter or battlespace network. The group suggested that the dispensed sensors be launched from the center carrier section by a spring and that the spring could also function as an antenna (Note: Assuming the spring maintains its coil like shape, this could be considered a helical antenna. Helical antennas can be good substitutes for conventional whip-like antennas in space limited applications, but the antenna dimensions must be small when compared to the wavelength of radiation being broadcast.[8]).

There were other attributes of the sensor described. The group also believed that the individual sensors would use a spring to propel them away from the carrier/dispenser package. The spring could also serve as an antenna. Mr. Edwards commented that the sensors ideally dissolve or at least become inactive after a fixed amount of time. More importantly, Mr. Edwards felt the sensor network needed to gather enough information that a fire/no-fire decision could be made without a visual confirmation of the target. Mr. Goddard noted that these sensors are all available but are comparatively large. He felt that technology needed to

[8] Tom Yestrebsky, MICRF001 Antenna Design Tutorial, Micrel Corporation, http://www.micrel.com/_PDF/App-Notes/an-23.pdf (retrieved July 14, 2010).

model insect sensory apparatus to achieve miniaturization. The group noted the DARPA Hybrid Insect microelectromechanical systems (HI-MEMS) program is addressing this:

> *The HI-MEMS program is aimed at developing tightly coupled machine-insect interfaces by placing micro-mechanical systems inside the insects during the early stages of metamorphosis. These early stages include the caterpillar and the pupae stages. Since a majority of the tissue development in insects occurs in the later stages of metamorphosis, the renewed tissue growth around the MEMS will tend to heal, and form a reliable and stable tissue-machine interface. The goal of the MEMS, inside the insects, will be to control the locomotion by obtaining motion trajectories either from GPS coordinates, or using RF, optical, ultrasonic signals based remote control.*[9]

It was noted that the sensors should be *organic to the warfighter*; in other words, the sensor information should flow back to the warfighter who launched the package initially instead of being broadcasted through a battlespace wide network. This is not to say that the information should not be relayed to other groups, but keeping the information locally provides a backup in case communications fails.

The group named this concept the *Spider*, since it launches a web of sensors that send information back to a central point, much like a spider does while sitting in the middle of its spun web. The group also noted that many of the sensors are already available, but they need to be miniaturized and integrated. This integration also includes acceleration hardening.

The group also discussed firing a single, larger sensor that would spool out a fiber optic cable back to the launcher. Although wire trailing projectiles are not new, substituting a fiber optic cable would greatly increase the amount of data that could be streamed back to the launcher. A concern was the cable could become kinked, resulting in data loss. Additionally, it was noted that the standard 40 mm round has an effective 400 m range, and the cable diameter would have to be exceptionally fine to carry enough on a 40 mm form factor spool.

Mr. Goddard also noted that fiber optic cable is also available that is very strong and could be trailed out the rear of the round. This would enable high bandwidth communications. Fiber is designed for use to bring fiber into the home. Mr. Pollock noted that historically trailing lines are considered to be problematic, although he noted that the fibers would solve many issues.

It was noted that since this is a single sensor package instead of a large number of sensors being launched in a 40 mm form, the miniaturization requirements are relaxed. Indeed, Mr. Edwards noted the similarities to the Small Arms Deployable Sensor Network (SmADSNet) and DARPA Expendable Local Area Sensors in a Tactically Interconnected Cluster (ELASTIC) programs. These sensors are for building occupant identification and are constructed of commercial technologies that have been hardened for ballistic launch.[10] Although several

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[9] DARPA HI-MEMS http://www.darpa.mil/mto/programs/himems/index.html (retrieved July 23, 2010).
[10] ARDEC Technology Transfer Program, http://www.pica.army.mil/TechTran/tech_highlights/ (retrieved July 23, 2010).

group members wondered if such a device is real or simply a concept, it should be noted that there are already cameras incorporated in 40 mm grenade forms; for example, the Martin *HuntIR™*, the Singapore Technologies (ST) Kinetics *SPARCS™* and Rafeal Armaments *FireFly™*.

Group B then turned its attention to *defeating the soldier of the future*. Mr. Goddard noted that technology proliferation had reached a stage where the best, or close to the best, equipment can be purchased by any group with the necessary funds. Mr. Goddard specifically noted body armor, noting that a well protected adversary significantly shrinks his vulnerable target area, requiring superior marksmanship for effective shooting.

The group then considered different ammunition types. One person suggested flechettes. These are small arrow like projectiles as opposed to a blunt bullet. Their small frontal area and long length make them superior for armor piercing.

Group C: Fire Control

Mr. Shisler's group was charged with fire control. He indicated that this means "*…a number of things. It probably means displays; it probably means networks, sights, an indication of where the target is… and situational awareness."*

The group began by describing what this device should be. Mr. Edwards, who was sitting in on this group, commented that a fire control device is a *sighting system that aids in weapon system delivery by sensing, estimating, and compensation.* He further indicated that the device should operate by displaying a corrected aim point or a value that can be entered into a fire control device. Mr. Zurlo added *the sighting system should protect the soldier*.

In addition to *situational awareness* the group decided to make the weapon sight *the graphical user interface that allows the warfighter to interact with his weapon or higher up in terms of delivery of effects*. Suggested features of this enhanced sight included combat identification, target hand-off, and performing beyond line-of-sight (BLOS) fires.

One area discussed and rejected was *battle damage assessment in near real time* as a prelude to reengagement if necessary. It was noted that this was an unknown area. Heavier systems like artillery do not have a good way to do this other than by reconnaissance. It was deemed impractical for the rifle bearing soldier.

The group also discussed the concept of *virtual weapons*. Similar to a video game controller, this would be a rifle or pistol like device that would direct the fire from a completely separate device. A virtual weapon would give the warfighter the ability to call on additional weapons that are not part of the warfighters equipment (termed inorganic weapons) – a robot, a CROWS type weapon or an UAV for instance. Removing the weapon and ammunition from the warfighter also reduces his weight burden.

The issue of power storage and distribution was also discussed. Currently weapons use separate systems with dedicated power sources; for example, a flashlight mounted on the front of the weapon uses it own battery, night vision systems use their own batteries, and so on. Using a centralized power system, either carried by the soldier or beamed from a remote source, could alleviate some of these issues. In particular, *remote power transmission*, where some or all of the energy needs of the warfighter is delivered wirelessly, was suggested. It was noted that there is progress in this area – in particular, a product called WiTricity™, which claims to be able to transmit energy to devices in a room sized area.[11] Although it was decided that practical wireless energy transmission may be well into the future, it was decided to include this as well. It was also noted that other power sources like fuel cells and power harvesting are in development and will become available over time.

Mr. Edwards noted that the discussion was ranging between purely technical aspects and tactical aspects. It was decided that both are needed.

The discussion initially considered the role of the fire control sight in the overall situational awareness. This includes the relative position of friendly forces as well as enemy forces and noncombatants. The discussion initially continued on Mr. Edward's theme of the fire control device acting as an interface between the individual warfighter and his fellow squad, platoon and higher elements of the battle environment. Mr. Holmes raised the question of reducing the amount of information the warfighter receives. Does the warfighter receive all information possible, which may overwhelm him, or is there some level of reduction or summarizing that occurs that may be based on the warfighter's location? Is the information held by one person or is it freely available to everyone? Should the warfighter be a dumb node in the information network, only receiving information, or be an intelligent node, with the ability to receive, send and synthesize information?

Other discussion points included:

- Ability to engage targets that are not in or beyond the line of sight of the warfighter
- The ability to remotely fire the warfighter's weapon, thereby protecting the warfighter
- Combat identification (tag and mark, facial recognition)
- Massed or synchronized fires
- Power – transmit and receive, energized weapon rails, and generation
- The ability to call on additional weapons that are not part of the warfighter's equipment (termed *inorganic weapons*) – an UAV for instance.

The group evaluated their concepts according to the paradigm suggested by Mr. Ostuni:

- Technology – Although technology is advancing rapidly, there is a question as to how much would have to be developed or derived as opposed to using COTS based solutions.
- Cost – This was viewed as a negative factor, due to the development costs.

[11] WiTricity Corporation, http://www.witricity.com/ (accessed January 19, 2010).

- Effectiveness – The group decided that this was largely favorable due to the outcome on the warfighter.
- Time to availability – It was decided that this was a negative.

The group believed the return on investment would be tremendous, since such a device would greatly enhance warfighter survivability. This was attributed to an increased situational awareness. They would restrict the information available, however, to the warfighter's immediate area of influence, which would include members of his fireteam, squad and immediately adjacent squads as well.
Mr. Ostuni suggested the group focus their efforts on three options, with one being the idea of a virtual weapon.

Proposed Solutions and Development Timeframes

As noted, the individual groups evaluated the technologies according to a paradigm in

Table **3**. Each group populated an evaluation form that modeled this paradigm. The groups formulated several ideas that are summarized in **Error! Reference source not found.**.

At the end of the conference seven of these forms were completed. Each of these is presented along with a commentary as to their likely technical maturity, investment worthiness, and suggested investment timeline.

Table 5 - Summary of Workgroup Ideas

Topic Area	Solution Title	Description	Timeframe
Energy Usage	(None given)	To demonstrate the ability to collect / transmit 2-4 watts from the soldier to the weapon; to benchmark the technology; to quantify the benefits, needs, requirements, impacts and trade-offs.	2012 to 2017
Target Engagement	(None given)	Make the weapon scope a fully functional display and computing device to heighten warfighter's situational awareness.	
Target Engagement	SPIDER integrated sensor system	SPIDER integrated sensor system for situational awareness sent to a scope with markers for friend, foe or unknown in the view as the weapon is panned (day/night, all weather) with targets in defilade or BLOS.	2012 to 2014
Target Engagement	Big Fish	Launchable video camera connected to warfighter via fiber optic cable.	2012 to 2014
Target Engagement	Scalable non-lethal to lethal	Several possible directed energy weapons were considered – laser, microwave, acoustic, vortex ring, and plasma.	
Target Effectiveness	Door breaching	Remotely (15-75M away from the target) breech man-sized holes in walls (i.e., reinforced concrete) and doors from a small arms platform.	2012 to 2014
Target Engagement and Target Effectiveness	(None given)	Defeat the soldier of the future who is similarly armed, equipped and supported.	2012 to 2014

I. Energy Usage

This was considered by *Group C*. Although it is in the energy usage focus area, they listed the topic area as **Fire Control**, presumably since night vision scopes and the like are the largest energy consumers on the weapon. Their proposal is given below:

TECHNOLOGY ASSESSMENT FORM – ENERGY TRANSMISSION AND GENERATION

Topic area: **Fire Control**

_X_ Energy Usage ___ Target Effectiveness ___Target Engagement

Goal: To demonstrate the ability to collect / transmit 2-4 watts from the soldier to the weapon; to benchmark the technology; to quantify the benefits, needs, requirements, impacts and trade-offs.

Assumption: Basic weapon fire control system would require a minimum power supply of 2-4 watts.

- Demo in about 2-4 years (2012) to assess trade-offs, assess power needs, power management, power base-lining, use of hot rail
- Identify state of the art, limitations, potential areas to invest
- Pieces: power management, power harvesting, energy transmission from the soldier
- Identify areas with the potential to harvest power (immediate use and storage)
    - Heat from the weapons
    - Recoil attenuation
    - Moving parts

Title: (Not given)

1) What is the problem?

Must provide power, yet power supplies and power resources have limitations. There is no ability to manage power on the weapon system. Soldier weapons are becoming increasingly heavy, battery supplies (logistics). Weapon power supply must be immediately available as there is a limitation on the ability to generate and transmit power to the weapon systems.

- Reduce cost
- Elimination of variance and waste
- Increasing Operational Tempo (OPTEMPO)
- Reduce soldier load
- Increase efficiency
- Save soldier's lives
- Reducing risk on multiple levels
- Reduces environmental impacts

2) What are the barriers to solving this problem?

- Power and energy density
- Efficiency for transmission and harvesting
- Ability to mask transmission signature to enemy forces

3) How will you overcome those barriers?

- Leverage national laboratories / government labs
  - Soldier Systems / Natick Labs
  - CERDEC (Wireless / batteries)
  - TARDEC (power for the soldier system)
- Engage technologies ready to exploit
- Leverage commercial technologies
  - WiTricity™
  - Nokia (wireless transmission of power to devices (cell phones))
  - Existing networking technologies like Wireless Fidelity (WiFi)
  - Computing power (faster processors / smaller size / memory)
  - Unattended ground sensors
  - USAF Miniature Unmanned Aerial Vehicles
  - Distributed Power generation / centralized storage of power
  - Power management – locate battery in one location – then power management (focus on 2-4 watts)

4) What is the capability you are developing?

- Reduce the weapon carry weight (load) carried by the soldier
- Positively affect the logistics / resupply / need to carry a battery supply
- Reduce the number of power sources required by making use of battery consolidation
- Manage power across the weapon system and supporting fire control devices
- Offset power use by power harvesting

5) What is the result of this Technology investment & application?

- Establish a baseline for power requirements for the weapon / systems and the potential for future power transmission
- By leveraging possibility of wireless power transmission could provide the opportunity to provide additional functionality (devices) which may not currently be able to be weapon mounted
- Provide the basis for future development work in power transmission

6) Leverage

- Laboratories
- Universities (Rapid Recharge technologies)
- CERDEC
- Night Vision Lab
- Natick Soldier Lab
- Universities / Not for Profit
- Battelle Memorial Institute
- In-Q-Tel
- DuPont
- Ultracell
- Nokia
- Adaptive Materials
- SFC Technologies

7) When in the 2012-2020 period should the investment occur?

- 2012-2014: Demonstration / Benchmark Power Transmission and Consolidation

- 2015-2017: Further refinement depends on the demonstration / baseline effort

Commentary on the current State of the Art and Timeline

The group addresses several topics in the energy usage area. The focus is on removing the battery or batteries from the weapon and supplying necessary weapon power wirelessly. In addition the group suggested generating power in the field.

Overall, the timeline in this area may be reasonable, although there will have to be several breakthroughs that will have to occur before the goals as outlined by the group occur.

The group began with this statement:

- Establish a baseline for power requirements for the weapon / systems and the potential for future power transmission.

Because this problem is ubiquitous across all branches of the military, it has been and continues to be scrutinized. The current and future power needs of the dismounted warfighter have been discussed:

> *According to the U.S. Defense Dept., the average power load of a nine-man rifle platoon is 10.3 watts per person, with an average use of 12.3 watts per soldier. Within a decade*

or so, soldiers will need about 50 watts of power. To put the numbers in perspective, the average 72-hr. mission requires 885 watt-hr. of energy, or 5.9 kg. (13 lb.) of batteries. A 96-hr. mission requires 1,181 watt-hr. of energy, or 7.9 kg. of batteries.[12]

The *National Research Council* (NRC) has also discussed warfighter power; publications from the NRC include "Energy-Efficient Technologies for the Dismounted Soldier" and "Meeting the Energy Needs of Future Warriors."[13]

Efforts are underway in several military branches to address this concern. For instance, the Air Force Research Laboratory Materials and Manufacturing Directorate held a competition between 2007 and 2009 to:

… identify lightweight, wearable power systems that meet the technical criteria for enabling reliable communications and other vital capabilities required in today's high-tech environment. The competition included a 92 hour continuous bench test, in which varying power loads up to 200 watts were placed on the systems, with an average draw of 20 watts. Entries had to weigh less than 4 kilograms (8.8 pounds) and be attachable to a standard military vest. [14]

The top three competitors used wearable fuel cells. Rather than powering weapon mounted devices directly, the fuel cells recharged batteries that could be inserted in the battery operated devices as necessary. While this is not an ideal solution, since the warfighter has to change batteries, it alleviates logistics issues.

Group A discussed wireless power transmission, specifically noting the *WiTricity* *Corporation* as an example of a wireless electricity transmission developer. The device uses a magnetic coupling mechanism and the company principals have published scholarly articles on their device. One article provides insight into their technology:

A recent theoretical paper presented a detailed analysis of the feasibility of using resonance objects coupled through the tails of their nonradiative fields for midrange energy transfer. Intuitively, two resonant objects of the same resonant frequency tend to exchange energy efficiently, while dissipating relatively little energy in extraneous off-resonance objects. In systems of coupled resonances (e.g., acoustic, electromagnetic, magnetic, nuclear), there is a general "strongly coupled" regime of operation. If one can operate in that regime in a given system, the energy transfer is expected to be very efficient. Midrange power transfer implemented in this way can be nearly

[12] BH Chavanne, *R&D Targets Lightweight Power-Generation Devices*, Aviation Week.

[13] Committee on Electric Power for the Dismounted Soldier, National Research Council, **Energy-Efficient Technologies for the Dismounted Soldier**, 1997, http://books.nap.edu/catalog.php?record_id=5905 (accessed August 17, 2010) and Committee of Soldier Power/Energy Systems, National Research Council, **Meeting the Energy Needs of Future Warriors**, 2004, http://books.nap.edu/catalog.php?record_id=11065 (accessed August 17, 2010).

[14] P Meltzer, *AFRL lends expertise to warfighter power pack competition*, Inside WPAFB, March 6, 2009 http://www.wpafb.af.mil/news/story.asp?id=123138611 (retrieved July 15, 2010).

omnidirectional and efficient, irrespective of the geometry of the surrounding space with low interference and losses into environmental objects.[15]

The same article further states:

> *Although the two coils are currently of identical dimensions, it is possible to make the device coil small enough to fit into portable devices without decreasing the efficiency. One could, for instance, maintain the product of the characteristic sizes of the source and device coils constant….*[16]

Intel also demonstrated this phenomenon at its developer forum in 2007, where up to 60 watts was transmitted several feet. However, there is a difference between the *efficiency of coupling* and the *efficient transfer of power*. The New York Times article that describes the demonstration notes the group *…demonstrated efficiencies of 50 percent at ranges of several meters*.[17] In other words, while it appears the technology is capable of retrieving the power transmitted efficiently, there is, not surprisingly, a loss of the amount of power available as the distance between the source and destination separate.

Microwaves have also been researched for wireless energy transmission. The National Air and Space Administration (NASA) sponsored university research into microwave based wireless power transmission as a means of sending power to satellites. The group was able to fabricate and demonstrate the necessary transmission, reception and conversion components of such a system. Efficiencies were estimated as being approximately between 50% and 75% for each component, leading to an overall transmission and reception efficiency of about 25% of the power from the source.[18] Of particular note were the small sizes of the devices; photographs in the referenced presentation show the actual devices as being coin sized or smaller, although they are soldered on a much larger copper sheet which may be necessary for heat removal.

These are wireless power transmission possibilities that have already advanced to a reasonable level of technical readiness. The offering from *WiTricity Corporation* suggests that wireless transmission from somewhere on the warfighter's person to the weapon is feasible, although the effects of the weapon metallic parts would have to be considered on magnetic-based power transmission. The NASA work suggests transmitting power from a greater distance to the warfighter may also be technically feasible, although there are a number of questions like the affect on signature that would have to be answered. Overall, the question becomes integrating this to the warfighter's weapon and uniform ensemble.

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[15] A Kurs, et al *Wireless Power Transfer via Strongly Coupled Magnetic Resonances*, Science, 317,(July 6, 2007) pg. 83.
[16] *Ibid*., pg 85.
[17] J. Markoff, *Intel Moves to Free Gadgets of Their Recharging Cords*, The New York Times, August 20, 2008, http://www.nytimes.com/2008/08/21/technology/21intel.html (accessed July 13, 2010).
[18] J. Lin, et al, *Remote Wireless Power Transmission for Regenerative Fuel Cells*, Florida Universities Hydrogen Review 2005, http://www.hydrogenresearch.org/NRM_Nov05/UF-Lin-Remote%20Wireless%20Power%20Transmission-Nov05.pdf (retrieved July 13, 2010).

Increasing the power reserve of the warfighter by power harvesting or scavenging was also considered. Power harvesting refers to using some form of kinetic energy that is a result of some other action to generate power. Mr. Edwards noted that some research had been done on using rifle bolt recoil to generate electricity. A cursory search of the Internet using the term *power harvesting* showed a number of entries related to human powered computing for instance. One of the early works in this area described using piezoelectric devices embedded in the shoe to provide between 5 and 8 watts of power through brisk walking.[19] These may also be used to alleviate battery needs of the warfighter.

One area that was not specifically addressed but should be included is power management for weapon systems. Although not discussed, a system that can place a powered weapon optic in a standby mode when it is in a neutral position (for example, pointed downward) would positively impact the power requirements for the warfighter.

[19] T. Starner, *Human Powered Wearable Computing*, IBM Systems Journal, 35 (3/4), 1996, http://www.cc.gatech.edu/~thad/p/journal/human-powered-wearable-computing.pdf (retrieved July 15, 2010).

II. Target Engagement

Groups *B* and *C* both suggested displaying situational awareness information in the weapon sight. *Group B* considered a sensor network that would display information in the warfighter's scope. *Group C* presumed that the sensor network either existed or else the scope integrated information from various sources. The technologies are below, with Group C's contribution being considered first because of its narrower focus.

TECHNOLOGY ASSESSMENT FORM – SCOPE INFORMATION DISPLAY

Topic area: **Fire Control**

___ Energy Usage ___ Target Effectiveness _X_ Target Engagement

Purpose: To demonstrate the ability to take sensor information and to display it on an individual soldier's rifle using a thermal or CCD image technology. The sensor information (e.g., range, azimuth to target) being shared may also come from other sources such that there is greater situational awareness of where potential enemy threats are located.

1) What is the problem? (Why are we making the investment?)

Goal: To increase survivability (e.g., save soldier lives), lethality, access to greater situational or battlefield awareness (e.g., threat information, target ID), information sharing (e.g., peer-to-peer), which reduces risk at many levels, facilitates battlefield dominance, integrates system processes and enhances OPTEMPO.

2) What are the barriers to solving this problem?
(Identify key technical and manufacturing barriers to success?)

Barriers are as follows: (assumed to be independent of available funding)

- Restricted to laws of physics
- Weight, power, and size
- Miniaturization
- Computing power and processing
- Bandwidth
- Environments
- Instantaneous transfer of information exchange
- Training
- Soldier acceptance
- Maintaining the reliability of the network (e.g., protocols, jamming, security, EMP sensitivity, hardening)

3) How will you overcome those barriers? (Identify specific solutions.)

Barriers can be overcome by leveraging technologies which are leaders in the field:

- Wireless technologies
- Commercial technologies (e.g., Motorola DROID, iPod, wireless industries, WiTricity, phone widgets/applications)

- Technologies which are ready to exploit (e.g., mobile phone technologies), computer assisted image identification
- Exploitation of display technologies / sensor fusion, networking technologies (e.g., Bluetooth, Wi-Fi), advancements in computing technologies / processing power, filtering / storing large amounts of information
- Camera related technologies for image recognition
- Ability to overlay information (e.g., icons) on sight displays (viz., the layering of digital information).

4) What is the capability you are developing? (Capability gap or enabler.)

- Visual information sharing among individuals on the battlefield
- Power management
- Equipment hardening
- Take acoustic information (heart beat, language) into this too. Add acoustic sensors to ID and locate targets – listening to determine target ID and location.

5) What is result of this Technology investment & application?

- Tag / mark
- Target identification / location
- Situational awareness
- Power management
- Combat ID
- Common operating picture
- Greater lethality and soldier survivability
- Integration across the soldier system to effectively engage target(s)
- Increased OPTEMPO
- Effective / efficient targeting by using increased situational awareness and shared information to engage the target with the best delivery system
- Decreased need for resources (e.g., personnel requirements to complete the same mission)
- Reduction of friendly fire casualties
- Reduced mission costs

6) What are other leveraging technology programs? (Who are the leaders in the field of research and in applications?)

- National laboratories / other government labs (e.g., Night Vision / Sensor Fusion)
- Natick Soldier Lab
- CERDEC
- Government contractors / companies (e.g., Harris, General Dynamics, BAE, L3, Raytheon, ITT, Microsoft, Apple, Thales)

7) When in the 2012-2020 period should the investment occur?

- 2012-2014

JSSAP should invest in 1st generation fire control

  - Scope
  - Capability to collect and integrate information into the display (where is the target?)
  - Should not be confusing to the receiver (disorientation)
  - Digital "overlay" into the soldier's sight picture
  - Multiple targets can be identified and selected (see all threat targets which can be prioritized)
  - Potential targets (friend and foe)
  - Digital (day / night capable)
  - Paint with laser / keep painted until the system recognizes the target
  - System receives GPS information (shooter location)
  - Range to target (input)
  - Image recognition (visually)

- 2015-2017

  Further refinement depends on the demonstration / baseline effort

  2nd Generation

  - Scope
  - Add tag and mark
  - CCD or thermal
  - Prioritization / engagement of targets – given current tactics / observers / military, etc.

- 2018- 2020

  3rd Generation

  - Virtual weapon & heads up display
  - Behavioral characteristic identification / target threat assessment

Commentary on the current State of the Art and Timeline

For the 2012 – 2014 period the group specified that the warfighter's fire control device would collect and integrate information about multiple targets in the field of view. The recommended investment timeline may be reasonable. It should be noted that this is very similar to the helmet and digital battlefield sections of the *Land Warrior* program:

> *The **Integrated Helmet Assembly Subsystem (IHAS)** uses advanced materials to provide ballistic protection at less weight than the current helmet shell. The integrated helmet assembly is lighter and more comfortable than today's helmet. **The IHAS's helmet mounted computer and sensor display is the soldier's interface to the other subsystems and to the digital battlefield. Through the helmet mounted display, the soldier can view computer-generated graphical data, digital maps, intelligence information, troop locations and imagery from his weapon-mounted Thermal Weapon Sight (TWS) and video camera** (emphasis added). This new capability allows the soldier to view around a corner, acquire a target, then fire the weapon without exposing himself, beyond his arms and hands, to the enemy. By scanning an area with his weapon's thermal sight, the soldier will be able to see an area's characteristics, including terrain and enemy positions, and will be able to see through obscurants. The thermal images will appear on a miniature helmet-mounted display. The Night Sensor Display will integrate a helmet mounted display with an image intensifier for access to his computer sensors as cited above. This will allow the soldier to maneuver and engage targets under cover of darkness.*

and

> *The infantryman will attach the **Computer/Radio Subsystem (CRS)** to his load-bearing frame. Over this goes the rucksack for personal gear. The computer processor is fused with radios and a Global Positioning System locator. A hand grip wired to the pack and attached to the soldier's chest acts as a computer mouse and also allows the wearer to change screens, key on the radio, change frequencies and send digital information. The subsystem comes in two flavors: The leader version has two radios and a flat panel display/keyboard, and soldiers have one radio. **With the equipment, leaders and soldiers can exchange information. Soldiers using their weapon-mounted camera, for example, can send videos to their leaders** (emphasis added). In its GEN II version, the computer and radio will be combined and embedded in new web gear. The system will be built around a series of cards the size of credit cards, but slightly thicker.*[20]

It appears the primary difference between the **Land Warrior** system and the suggested technology will be to integrate the system on the weapon scope as opposed to the warfighter's person. This reduces the problem down to two major parts; namely, giving the scope enough

[20] Federation of American Scientists Military Analysis Network, August 7, 1999, http://www.fas.org/man/dod-101/sys/land/land-warrior.htm (retrieved August 3, 2010).

intelligence to perform the IFF and other tasks assigned to it and updating the display in real time as the sight is panned.

It should be noted that there may not be any functional difference between placing the necessary computing power on the weapon scope versus using a computer on the warfighter's equipment frame and relaxing the scope's function to a monitor. The advantage to this is that it removes weight from weapon. The scope will have to bi-directionally communicate to the computer in real time however, since the scope picture will have to be examined by the computer and the results sent back to the scope for display. This may require a fiber optic or copper wire tether between the warfighter's computer and the weapon, which has been considered undesirable. Conversely, a low power wireless personal network could be used if the necessary speed and transmission/received accuracy could be obtained.

Unfortunately all objects visible in the weapon sight must be continually processed. The problem is further compounded when the person or object being tracked is moving in a cluttered environment, requiring re-acquisition every time the person disappears and reappears, likely in changing conditions of light and shadow.

Overall, this becomes a machine vision problem in varying conditions of light and pose (that is, orientation of the object relative the camera). This is a classical problem in machine vision and biometrics applications and is being investigated by a number of entities, primarily for security applications. For instance, one university group investigated facial recognition using video imagery with good results in a laboratory environment:

> *Finally, we demonstrated the effectiveness of the method on video databases with large and arbitrary variations in pose and illumination. Future work will concentrate on applying these methods for tracking people in outdoor environments by integrating appearance and identity information in occluded and cluttered environments.*[21]

The other aspect of the problem is updating the sight view in real time as the warfighter moves and changes orientation. This also has been investigated for gaming applications where the player is interacting inside a digitally augmented real world. An example of this was noted in 2005, when workers in Singapore showed a digital/real world fusion of the *PacMan* computer game:

> *Players equipped with a wearable computer, headset and goggles can physically enter a real world game space by choosing to play the role of PacMan or one of the Ghosts.*
>
> *A central computer system keeps track of all their movements with the aid of GPS receivers and a wireless local area network.*

[21] Y. Xu, A. Roy-Chowdhury, K. Patel, Pose and Illumination Invariant Face Recognition in Video, http://www.ee.ucr.edu/~amitrc/cvpr07-biometrics.pdf (retrieved August 2, 2010).

Merging different technologies such as GPS, Bluetooth, virtual reality, Wi-Fi, infrared and sensing mechanisms, the augmented reality game allows gamers to play in a digitally-enhanced maze-like version of the real world.[22]

What cannot be quantified is whether or not the necessary hardware can be integrated into a weapon sight. Certainly the augmented reality work suggests that it is possible, and the *Land Warrior* work suggest that small, robust displays can be developed as well. It is suggested that if investment is desired, that it initially be done as the group suggested; that is, it be done as a laboratory mock-up that does not emphasize the necessary hardware miniaturization and packaging so the problem can be quantified fully.

[22] L. Sandhana, PacMan comes to life virtually, BBC on-line. June 6, 2005, http://news.bbc.co.uk/2/hi/technology/4607449.stm (retrieved August 3, 2010).

TECHNOLOGY ASSESSMENT FORM – SPIDER 40 MM LAUNCH SENSOR NETWORK

Topic area: **N/A**

___ Energy Usage ___ Target Effectiveness _X__ Target Engagement

Title: SPIDER integrated sensor system for situational awareness sent to a scope with markers for friend, foe or unknown in the view as the weapon is panned (day/night, all weather) with targets in defilade or BLOS.

1) What is the problem?

- Inability to determine where the target is (hidden targets, BLOS)
    - Lack of automated moving target location
    - Lack of automated tagging
    - Lack of aided marking
- Inability to determine what, or who a target is accurately (Identification)

2) What are the barriers to solving this problem? (technical)

- Don't have the sensors
- Sensor fusion
- Hard to share the information
- Size
- G-hardened

3) How will you overcome those barriers?

- Use ultra miniature sensors TRL-2
- Miniaturization of current sensors TRL-5
- Develop g-hardened sensors for 40mm grenade TRL-5
- Develop distributed sensor networks to provide enough information to locate targets (300m in defilade) TRL-5

4) What is the capability you are developing?

Ability to locate and identify hidden targets using a distributed sensor network delivered by a 40mm grenade and fed to a scope on the infantry weapon.

5) What is result of this Technology investment & application?

More effective situational awareness for force application and protection which can be delivered by a 40mm grenade or other platforms.

6) Leverage

- Other programs that are doing UGS work
- DARPA HI-MEMS
- IAWS and Excalibur
- The Small Arms Deployable Sensor Network (SmADSNet)
- Special Operations Force Network (SOFNet) for sensor and information integration (Cursor on target, CoT)
- COTs equipment (watch batteries, security industry, hearing aids)
- Remington tossable camera and microphone
- Opportunistic hopping out wireless transmissions to avoid detection and conserve power - frequency agile.

7) When in the 2012-2020 period should the investment occur?

- 2012-2014: The basic components are available. What is lacking is the integration and over time the miniaturization that enables more sensors and more capable sensors.

<u>Commentary on the current State of the Art and Timeline</u>

Briefly, the group is conceiving of a small 40 mm grenade that can launch sub-sensors in a designated area. The grenade would scatter the sensors and act as a central radio relay point.

This technology has been discussed for over a decade. For reasons that will be delineated, it is recommended that no investment be made in this area over the near term.

To begin with, in many ways this is similar to the *Smart Dust* efforts that were funded by DARPA at the University of California, Berkley in the late 1990s. Dr. Kris Pister, the lead investigator for this effort, noted the goal of this effort was to develop *…a complete sensor/communication system can be integrated into a cubic millimeter package*.[23] Achieving this size has proved elusive. Much of the work in this area has instead concentrated on developing sensor networks with tens, hundreds or even millions of individual sensors.[24] While these sensors are small, they will not achieve the aspirin sized sensors being envisioned here.

Dr. Pister informally noted some physical limits to transmission power and similar attributes in a web posting. His comments are reproduced below due to their relevance to this and possibly other areas being discussed. It should also be noted that the Smart Dust sensors they

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[23] K. Pister, **Smart Dust: Autonomous sensing and communication in a cubic millimeter**, http://robotics.eecs.berkeley.edu/~pister/SmartDust/ (retrieved August 26, 2010).
[24] J. Sutter, **'Smart dust' aims to monitor everything**, CNN, May 3, 2010, http://www.cnn.com/2010/TECH/05/03/smart.dust.sensors/index.html (retrieved August 26, 2010).

envisioned used encoded laser pulses to communicate instead of radio waves. Dr. Pister likely made these comments in the late 1990s:

Acquiring a digital data sample from many sensors requires on the order of 1 nJ. Threshold detection at discrete time periods will require substantially less energy in most cases. Higher performance sensors will require more energy per sample, but the nJ/sample number is applicable to, for example: whisper-to-chainsaw acoustic, sub-degree accuracy temperature, milli- to kilo- gravity acceleration sensing (Which also provides tilt and vibration information), magnetic field to 0.1% of earth's field, barometric pressure to 5m, wind flow to 1 m/s, relative humidity to 2%, ambient light level and spectrum.

Transmitting a bit of data over 10-100 meters by RF today takes approximately 100nJ with Bluetooth, Wavelan, and other local area RF networks. Transmitting a kilometer takes 10 to 100 microJoules. These numbers are not likely to fall much, since they are often pushed up close to the fundamental physical limits. Another order of magnitude may be available by sacrificing immunity to unintentional jamming from nearby transmitters. If the dynamic range of the radio receivers is reduced, substantial improvements in power can be realized.

Collimated line-of-site optical communication systems will transmit 10m with an energy cost of 10pJ/bit, more than 10,000 times lower than existing radio technology. We have demonstrated 1nJ/bit in the lab already. This incredible gain over RF is due entirely to an antenna gain of roughly 7 orders of magnitude when going from an isotropic radiator to a 1 mrad divergence beam.

32 bit computation currently costs around 1nJ/instruction on power-optimized microprocessors. Engineering limits in the next 5 years or so are approximately 1pJ/instruction for dedicated hardware.

Good batteries provide roughly 1 J/mm^3. Solar cells provide approximately 100uW/mm^2 in full sunlight, more than 100nW/mm^2 in average room lighting. Vibrational energy available in an office setting is in the nW/mm^3 range. RF power in a simple antenna is generally not useful, unless there is a cell phone in use in the room, or a dedicated RF power source, in which case microWatts can easily be generated. Conversion is difficult, but feasible.

Assuming a simple task of sampling a sensor, performing some relatively simple processing (threshold, FIR/IIR filtering, statistical analysis, or FFT), listening for incoming messages, and transmitting a simple outgoing message, the energy cost will be a few nanoJoules.

Combining this with the power source information, a cubic millimeter battery will provide enough power to perform such a simple task once a second for 10 years. A cubic *millimeter vibrational energy rectifier will operate at that rate forever. Indoors a square millimeter solar cell will provide enough power to perform 100 tasks/second, or in full sunlight 100,000 tasks/second.*

For indoor optical line of sight communication, a cubic millimeter battery will provide enough energy to transmit 50 billion bits (roughly half a dozen full-length movies).[25]

[25] K. Pister, http://robotics.eecs.berkeley.edu/~pister/SmartDust/in2010 (retrieved August 27, 2010).

TECHNOLOGY ASSESSMENT FORM – BIG FISH

Topic area: **N/A**

___ Energy Usage ___ Target Effectiveness _X__Target Engagement

Title: Big Fish

1) What is the problem?

- Inability to determine where the target is (hidden targets, BLOS)
  - Lack of automated moving target location
  - Lack of automated tagging
  - Lack of aided marking
- Inability to determine what the target is (Identification) to a high degree
  - Unable to get high res video and audio
  - Unable to determine if they have guns or bombs hidden

2) What are the barriers to solving this problem? (technical)

- Light flexible fiber optic cable
- Small, light weight high resolution cameras
- Computer capable of accepting and integrating wideband information

3) How will you overcome those barriers?

- Adapt fiber optic cable technology TRL-5
- miniaturization of current sensors TRL-5
- Develop g-hardened sensors for 40mm grenade TRL-5
- Develop distributed sensor networks to provide enough information to locate targets (300m in defilade) TRL-5
- Remington tossable camera and microphone
- Opportunistic hopping out wireless transmissions to avoid detection and conserve power - frequency agile.

4) What is the capability you are developing?

Ability to locate and identify in detail hidden targets using a single high performance sensor package delivered by a 40mm grenade and processed by a computer that then sends information to the scope on the infantry weapon.

5) What is result of this Technology investment & application?

More effective situational awareness in that it provides much more detail about the target's characteristics. Secure and assured communications from the sensor to the user.

6) Leverage

- COTs equipment developed by Corning.
- General Dynamics Tactical Computer, Future Force Warrior computer

7) When in the 2012-2020 period should the investment occur?

- 2012-2014: The basic components are available. What is lacking is the integration and over time the miniaturization that enables a more capable sensor.

<u>Commentary on the current State of the Art and Timeline</u>

Overall, the timeline for this may be reasonable. There are two parts to this question; namely, incorporating a sensor package that can be launched in a 40 mm form factor and the availability of a fiber optic cable that is strong enough for this task. Sensor packages are likely not a problem, while the fiber optic cable requires a number of assumptions to quantify.

Currently there are already sensors incorporated into a 40 mm grenade form factor. For example, Martin Electronics has already developed and deployed a 40 mm low velocity reconnaissance grenade:

> *The HUNTIR (High-altitude Unit Navigated Tactical Imaging Round) consists of a cartridge-case assembly and an aluminium projectile body containing a first fire charge, a pyrotechnic delay column, an ejection charge, an Infra-Red (IR) CMOS camera and a parachute assembly. Upon firing the projectile assembly is propelled to an average altitude of around 200 m, the first fire charge ignites the pyrotechnic delay element, which ignites an ejection charge to eject the IR CMOS camera, which is attached to the parachute. The OV7930 IR CMOS camera uses the NTSC Composite video format and has an RF output of +20 dBm. It provides up to five minutes of real-time streaming video, using the 2,400-2,500 MHz frequency range, to any handheld device with a corresponding receiver up to a range of one mile line-of-sight.*[26]

[26] Jane's Ammunition Handbook, **MEI HUNTIR 40 mm LV video reconnaissance round (United States), 40 x 46 LV Other Grenades**, published January 12, 2010, http://www.janes.com/articles/Janes-Ammunition-Handbook/MEI-HUNTIR-40-mm-LV-video-reconnaissance-round-United-States.html (retrieved August 27, 2010).

Rafeal, an Israeli company, has a similar concept called the *Firefly* either in development or deployed.[27]

Therefore the key question is the fiber optic cable. There are too many assumptions that would have to be made before this is quantified. A search of the internet shows that there are no specific entries for high strength fiber optics that gives the necessary technical detail, possibly because these are bundles of fibers as opposed to single strands. One of the factors on the cable strength will likely be the diameter of the cable itself. The diameter will of course influence how much cable can be carried on a spool being trailed by the round (this presumes that the spool is on the round and not located externally on the weapon).

[27] Jane's Ammunition Handbook, **Rafael Firefly 40 mm LV video round (Israel), 40 x 46 LV Other Grenades**, published July 2, 2008, http://www.janes.com/articles/Janes-Ammunition-Handbook/Rafael-Firefly-40-mm-LV-video-round-Israel.html (retrieved August 27, 2010).

III. Target Effectiveness

As previously noted, *Group A* considered scalable lethal to non-lethal weapons that could be used between close quarter combat ranges to the limit of the warfighter's vision. The group believed there were two fundamental questions: 1) How does what the weapon projects interact with the target? and 2) How do you get effect on the target? Although *Group A* initially discussed both kinetic and non-kinetic weapons, they decided to discuss non-kinetic weapons exclusively – specifically directed electromagnetic energy (laser and High Power Microwave) and acoustic weapons.

TECHNOLOGY ASSESSMENT FORM – LETHAL/NON-LETHAL WEAPONS

Topic area: **Lethal / Non-Lethal**

___ Energy Usage ___ Target Effectiveness _X_ Target Engagement

Purpose: The purpose is to demonstrate across a spectrum of effects from non-lethal (NL) to lethal technologies which could be used to engage targets from ranges (CQB to long range).

1) What is the problem? (Why are we making the investment?)

Goal: To be able to engage targets at a variety of ranges with both non-lethal and lethal target effects.

2) What are the barriers to solving this problem?

Barriers are as follows:

- Restricted to laws of physics
- Weight, power, and size
- Miniaturization
- Computing power and processing
- Social, moral, law of war prohibitions

3) How will you overcome those barriers? (Identify specific solutions.)

Barriers can be overcome by leveraging technologies which are leaders in the field:

- Commercial technologies (e.g., high-power microwave (HPM))
- Investigate (outside of ARDEC perhaps with The Ohio State University) medical / physiological effects on the body which could be exploited in a lethal / NL manner
- Technologies which are ready to exploit (e.g., ring airfoil grenade, “airfoil toy”, etc.)
- ARDEC work (Perseus Project)
- Combine technologies which may be mature in their own right into a combined system (e.g., vortex carrier for odorants or fuel-air mixture)

4) What is the capability you are developing? (Capability gap or enabler.)

- Scalable lethal to NL system which is an innovative approach to a problem

5) What is result of this Technology investment & application?

- Scalable lethal to NL system which is an innovative approach to a problem

6) What are other leveraging technology programs? (Who are the leaders in the field of research and in applications?)

- ARDEC / Battelle Memorial Institute/ OSU
- National laboratories / other government labs (e.g., Night Vision / Sensor Fusion)

7) When in the 2012-2020 period should the investment occur?

(No response given)

<u>Commentary on the current State of the Art and Timeline</u>

Group A did not specify a timeline for investment. In some instances investment is being made and it is not worthwhile to invest further until it is known what the results of these investments are. In other cases the physical nature of the radiation makes a weaponized version of it doubtful, since most of the described weapons require a whole body exposure before they are effective and this is not likely in a battlefield. Finally, the group admitted that several of the possibilities they were considering were deployed in some fashion. It is recommended that a sufficient level of experience with these designs be accumulated before additional investment is made.

Specifically:

- **Lasers**

  Lasers were at the top of *Group A's* list of possible candidates, noting that there are numerous examples of deployed systems available to support weaponry (for example, target range finders and designators). The group indicated that the overall readiness of the laser is high, but it is not to a point where it could be deployed as a non-lethal weapon. *Group A* believed that if a laser could be deployed as a non-lethal weapon, it would have already been deployed by this time.

- **High Powered Microwaves**

  Group A noted that microwaves are the basis of a deployed vehicle mounted non-lethal weapon (Active Denial System or ADS) and thus the technology was considered mature. The group, however, indicated the size needed to be drastically reduced, although a multi-man portable version of the ADS is under consideration.[28]

[28] Alicia Owsiak, Joint Non-Lethal Weapon Directorate, personal communications, June 6, 2008.

- **Directed Plasma**

  A *Plasma* is a gaseous collection of charged particles.[29] Plasmas are therefore capable of delivering thermal and possibly electrical energy when the gas collides with a target. The group believed that a directed plasma burst would be fast and highly directional. *Group A* also noted that the plasma would likely be confined to line of sight targets. Plasmas are in use today for applications like welding, but the technology would have to be greatly scaled up and modified in order to make it a weapon.

- **Vortex Ring**

  A *vortex ring* is defined as *…a region of rotating fluid moving through the same or different fluid where the flow pattern takes on a toroidal (doughnut) shape*.[30] Vortex ring "guns" are available as toys. *Group A* felt that the vortex ring could be exploited as a carrier of other gases. For example, the vortex ring could carry a malodorant, an explosive gas mixture that can be ignited by laser, or plasma. The group also wondered if the ring could be explosively formed or driven. Non-lethal vortex weapons are being incorporated as add-ons to dedicated grenade launchers like the MK 19.[31]

- **Acoustic**

  Group A noted that a non-lethal acoustic weapon, the *Long Distance Acoustic Device* (LRAD), is already fielded. The LRAD uses an excessively loud signal for its weapon function. The group felt it could be converted into a better weapon. The LRAD speaker and associated electronics are large, and the LRAD is currently deployed as a fixed installation on board ships or vehicles like the HMMWV. *Group A* believed the eventual acoustic weapon had to be smaller and more portable.

The group discussed the use of any or all forms of radiation for weapons. The radiation types discussed will have different object penetration and physical/physiological effects that are dependent on the energy frequency. Because many of the physiological effects are well documented due to the possibility of exposure in industrial settings, some judgment can be made as to weapon effectiveness, and some may not be usable as weapons.

Gamma rays and X-rays are the highest energy radiations. Unfortunately, their use as a weapon, even a non-lethal one, is doubtful. Both are classified as ionizing radiation and are

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[29] What is a plasma? Los Alamos National Laboratory, http://public.lanl.gov/alp/plasma/ubiquitous.html (retrieved May 11, 2010).

[30] Vortex Ring, Answers.com, http://www.answers.com/topic/vortex-ring (retrieved May 11, 2010)

[31] George K. Lucey, Jr., **Vortex Ring Generator: Mechanical Engineering Design for 100-kpsi Operating Pressures**, Army Research Laboratory ARL-TR-2096, January 2000 http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA372518 (retrieved August 27, 2010).

usually able to penetrate most materials, even thick ones. Fatalities are usually a result of a massive whole body dose of ionizing radiation. Individual parts of the body can absorb radiation without being fatal; hence the use of highly targeted radiation therapy on cancer. Any weapon would have to use a large diameter beam, meaning that the power would also have to be scaled up as well, reducing the likelihood the weapon can be made man-portable.

Even then, the dose might not kill immediately but instead cause death over time as critical systems of the body shut down. For example, the digestive tract typically stops absorbing nutrients if subjected to a massive radiation dose. As such, an enemy combatant may remain functional, albeit briefly, after being exposed to a massive dose of ionizing radiation.

Microwave radiation is considered non-ionizing and is generally believed to affect the body by heating (microwave heating is used in the *Active Denial System* (ADS)). One safety document from Cornell University suggests that biological effects will occur when the whole body dose reaches 4 Watts per kilogram of body weight; for a 175 pound warfighter, this is about 320 Watts delivered energy over a large area.[32] Although microwave ovens are capable of producing this energy, it is doubtful if a sufficient amount of energy could be broadcast from a man portable design that could achieve the desired effect at useful ranges.

Laser radiation and acoustic energy are also non-ionizing and their physiological effects are frequency dependent. An infrared (IR) frequency laser could most likely be weaponized; certainly IR lasers are being considered for anti-missile, anti projectile and anti-improvised explosive device (IED) roles. When being used as a weapon against an individual, the laser will have to hit a critical organ to do damage. This is no different from a kinetic weapon--although there is no chance for secondary damage caused by a round ricocheting off other organs. In addition, depending on the radiated power, lasers may require a few moments to build up enough heat on a target before effects begin.[33] If the target is a person, chances are the person will simply move as a result of feeling the heat.

Acoustical weapons are also non-penetrating, although effects can be transmitted from the skin into organs. The physiological effects from an acoustic weapon will have a frequency and intensity dependence. Lower frequency or intensity sound may cause only discomfort, while higher frequencies or intensities may result in over-pressure like effects. One review stated that …*eardrum rupture occurs at approximately 160 dB; lung rupture may happen at 175 dB.*[34] By way of comparison, a jet engine may generate 130 – 160 dB.

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[32] Cornell University, RF & Microwave Safety Program, SOP RFS-1, Revision date 12/2009, http://www.ehs.cornell.edu/docs/Rad/RF_Microwave_Safety_Program_Guide.doc (retrieved July 6, 2010).

[33] CE Howard, *Laser weapons: Fact from Fiction*, Military and Aerospace Electronics, http://www.militaryaerospace.com/index/display/article-display/2388283170/articles/military-aerospace-electronics/volume-21/issue-60/special-report/laser-weapons__fact.html (accessed July 15, 2010).

[34] Roman Vinokur, *Acoustic Noise as a Non-Lethal Weapon*¸ Sound and Vibration, October 2004, pg 19 http://www.sandv.com/downloads/0410vino.pdf (retrieved July 6, 2010).

TECHNOLOGY ASSESSMENT FORM – DOOR BREACHING FROM SAFER DISTANCES

Topic area: **Breeching**

___ Energy Usage _X_ Target Effectiveness ___Target Engagement

Current Technologies: Simon / GREM (15-50M)

Title: Door Breaching

Concept: Remotely (15-75M away from the target) breech man-sized holes in walls (i.e., reinforced concrete) and doors from a small arms platform.

40 mm grenade with radial segments which deploy in flight focusing the shock waves to more effectively breach an obstacle. (Battelle Memorial Institute Proprietary)

Utilize advanced fire control to determine door (or wall) characteristics (i.e., hinge location, construction material(s), reinforcements, and thickness) and coordinate simultaneous launch of multiple 40mm munitions (i.e., four or more weapons) to successfully conduct the breeching operation.

Dispense sticky foam with embedded explosives over the door (or wall area) using optical detonator(s) (initiated by using RF or laser) to conduct the breeching operation.

Use robotic device (i.e., Radio Shack radio controlled truck) with organic device to emplace the shaped charge on the area to be breeched.

1) What is the problem?

Problem: Soldiers are exposed to hostile fire / observation when emplacing explosives / using other means to breech a building door.

2) What are the barriers to solving this problem?

Weight

- Recoil
- Size / warhead
- What is the door (knowledge of door composition); the weak link is the hinge
- What is the delivery system?
- Initiation is critical
- Most breeching systems are not normally man-portable
- Difficult to define the target (e.g., type of door, density, wall)

3) How will you overcome those barriers?

- Brute force vs. other techniques (only requires ~ ¼ lb of explosive to take door out)
- Embed explosives in sticky foam (issue is initiation)
- Mass fires / multiple engagements (adjust TTPs)
- Use optical detonators w/ explosive charge and ignite with a laser from a distance
- Use robotic device to remotely emplace explosives
- Integrate device into the weapon system to determine target density (e.g., RF scanner)
- Consider different small arms systems (e.g., 40mm and below)
- Collateral damage
- Fire “bladder type charge” from 40mm

4) What is the capability you are developing?

Ability for soldiers to remotely breech a door from a distance (e.g., across the street ~ 15-75M).

5) What is result of this Technology investment & application?

Reduces soldier exposure to hostile fire: saves lives.

6) Leverage

- Fire control
- Explosively Formed Penetrator (EFP)
- Dense Inert Metal Explosive (DIME)
- Compact laser / RF for explosive initiation
- Robotics

7) When in the 2012-2020 period should the investment occur?

- 2012-2014: Each can occur during this timeframe or earlier

Commentary on the current State of the Art and Timeline

As the group noted, there is already a grenade available called the *Simon* or *GREM* that is capable of breeching doors at a range of 15 to 40 meters or so. While adequate, there is a need for either better range or possibly more flexible weapons (e.g., increasing the angle from where the round can be used). This has been considered by other branches of the military; the Navy, for example, issued a RFI in 2008 for door breeching rounds.[35]

An unknown area is the degree of collateral damage the round can cause, either to the warfighter or to the persons behind the door. The GREM, for instance, is basically a shaped charge, and while the bulk of the energy is dispersed on the door, it is likely that some energy will go through the door, especially if the door is much weaker than the maximum for which the round is designed to breech.

Battelle Memorial institute has also proposed a system which may overcome some of the disadvantages of the GREM. The proposed door breaching round was intended to function similar to the GREM, however with enhanced capabilities. The proposed 40mm round offers greater range and standoff for the warfighter and would be filled with an inert metal explosive. The proposed round would include a proximity sensor that would unfold the round, disperse the explosive loading, and completely knock down the door instead of punching a small hole through it. The round could also be commanded to detonate in the "folded" position for close in uses designed to minimize collateral damage. It could also partially unfold and put holes through more substantial targets through partial jetting of the explosive fill.[36]

In examining the possibilities that the group suggested, it is recommended that the technology from Battelle be monitored for additional investment along the timeline suggested. If a sufficient level of effectiveness is demonstrated, additional investment can be made. Moreover, there are a number of 12 gauge door breeching rounds available. Since 12 gauge shotguns are mounted on bomb disposal robots already, it should not be difficult to use a stripped down version of a bomb disposal robot to bring a shot gun to the door. The remaining technical concepts disclosed should not be pursued at this time.

[35] US Navy, **40 MM Standoff Door Breaching Round Sources Sought**, Solicitation Number: N0016408RJM25, June 2008, https://www.fbo.gov/?s=opportunity&mode=form&id=6dc77ee09c1ff6229cab777a645b0d90&tab=core&_cview=1 (retrieved August 27, 2010).

[36] Richard Givens, Battelle Memorial Institute, personal communications, September 10, 2010.

TECHNOLOGY ASSESSMENT FORM – DEFEATING THE FUTURE ADVERSARY

Topic area: **N/A**

___ Energy Usage _X__ Target Effectiveness _X__Target Engagement

Title: Defeat the soldier of the future who is similarly armed, equipped and supported (supplies, materiel, command and control)

1) What is the problem?

- Inability to determine where the target's greatest vulnerability is (radio, face, legs, command, support equipment (vehicles) at long range
- Inability to attack the identified vulnerability

2) What are the barriers to solving this problem? (technical)

- Don't have the sensors for a small guidance system and seeker
- Sensor fusion to accurately locate the target's vulnerability
- Hard to share the information from other sensors/soldiers in real-time
- Acceleration resistant (*G-hardened*)

3) How will you overcome those barriers?

- Use ultra miniature sensors TRL-2
- Miniaturization of current sensors TRL-5
- Develop g-hardened sensors for 40mm grenade TRL-5
- Develop distributed sensor networks to provide enough information to locate targets (300m in defilade) TRL-5
- Miniature guidance system TRL-unknown
- Miniaturize a seeker TRL-unknown

4) What is the capability you are developing?

- Face targeting munition
- Field programmable 20-40mm HARM type guided munition to target cell phones or other radios
- Anti-personnel Top attack munition
- Stabilized scope turning every soldier into a sniper after long range identification
- Better recoil mitigation for rapid fire accuracy at long range
- Armor circumventing munition
- Multi-stage salvo type weapon system (SK94)

- Ability to locate and identify hidden targets' vulnerability using a distributed sensor network delivered by a 40mm grenade and fed to a scope on the infantry weapon.
- Tubular multilayered munition to defeat body armor
- Tubular longitudinally segmented (multiple long rod) to defeat body armor

5) What is result of this Technology investment & application?

More effective situational awareness for force application and protection which can be delivered by a 40mm grenade or other platforms.

6) Leverage

- Other programs that are doing UGS work
- DARPA HI-MEMS
- IAWS and Excalibur
- The Small Arms Deployable Sensor Network (SmADSNet)
- SOFNet for sensor and information integration (Cursor on target, CoT)
- COTs equipment (watch batteries, security industry, hearing aids,)
- Remington tossable camera and microphone
- Opportunistic hopping out wireless transmissions to avoid detection and conserve power - frequency agile.

7) When in the 2012-2020 period should the investment occur?

- 2012-2014: The basic components are available. What is lacking is the integration and over time the miniaturization that enables more sensors and more capable sensors.

Commentary on the current State of the Art and Timeline

The group is proposing an anti-personnel smart weapon. This is very similar to the GNAT infrared homing anti-personnel micromissile that underwent development in the 1980s.[37] A key difference is that while the GNAT was using a general infrared signal to lock and track on a target, the application suggested here is for a full machine vision system installed on a small diameter round.

The group suggested that this at least undergo initial development over the near term. This is outside the scope of JSSAP, and so it is recommended that activity be monitored without investment. As noted in the section on the SPIDER, the move to smaller sensors has received

[37] Eugene H. Farnum, **GNAT—An Infrared Homing Antipersonnel Micromissile**, Los Alamos National Laboratory report **LA-10213-MS**, March 1985, http://www.fas.org/sgp/othergov/doe/lanl/lib-www/la-pubs/00318644.pdf (retrieved August 27, 2010).

less attention than developing the necessary hardware and software to make large scale networks. Hence progress towards smaller sensors will likely be slow. In addition, there are formidable software and hardware issues that will have to be overcome before a practical system can be developed.

Conclusion

A third Futures Conference was held in accordance with the direction given by JSSAP. The goal was to identify technologies that should receive investment from 2012 to 2020. The conference was held at the Battelle Memorial Institute in Columbus, Ohio with participants from Battelle and JSSAP/ARDEC staff.

The discussion groups developed seven ideas. These were independently evaluated by the report author for feasibility and the appropriateness of the suggested investment timeline. Several have already seen development, generally as part of other military programs, although some have seen industrial development as well. Therefore many are achievable in the 2012 to 2020 timeframe JSSAP delineated.

A summary of the results and recommendations from the author's evaluation is given in Table 6:

Table 6 - Summary of Recommendations

Concept	Recommendation
Energy Usage	Recommend for investment
Scope Information Display	Recommend for investment
SPIDER	No investment
Big Fish	Recommend for investment
Lethal/non-lethal weapons	No investment
Breeching	Recommend for investment
Defeat Future Adversary	No investment

An additional question is *what underlying technologies should JSSAP invest in that would provide a greater return on investment?* This can be readily re-phrased to *what will give the greatest benefit to the warfighter, preferably with the least amount of time and financial investment?* It is the author's opinion that technologies related to fire control are the most pressing area of development. The reason for this is the trend towards the highly distributed battlefield, where, as Mr. Solhan stated in the 2008 conference, small combat units will have influence over larger and larger areas. Because of this, it is essential that the warfighter be able to deliver an accurate shot, preferably on the first sighting and identification of an enemy. Moreover, in order for the various fire teams and squads to defend and support each other, the ability for accurate BLOS fires must be given to all warfighters. This implies a highly intelligent weapon scope.

Thus, the two major areas recommended for development are hardened displays on the weapon scopes and power management. Hardening displays may be as simple as monitoring progress in the organic light emitting diode technologies (OLED). OLEDs are used for displays on mobile phones and other electronic devices. Power management should remain a high priority.

Commentary on the Futures Effort

The obvious first question that should be asked is - *How well were the objectives of the Future's conference achieved?* Mr. Goldman, the current director of JSSAP, seemed very pleased with the results. However, the author of this report is less sanguine about the results, since many of the technologies that were suggested have seen significant development – there was nothing truly novel suggested.

This is not to say that the conference had no benefit; one of the problem areas identified was that there is no good way for the government to remain current with technological advances. These conferences, populated with the right personnel, can provide this knowledge.

This last condition suggests the path these conferences should take. JSSAP specified certain areas they wanted explored prior to the conference beginning, which is consistent with the 1986 conference, as well as many of the subsequent ones. To this end, participants were selected who had experience in these areas. For example, one of the three areas was Target Engagement which was defined as:

> *Improving the warfighter's ability to engage the target. This includes better sighting, the ability to mass fire, and engaging Beyond Line of Sight (BLOS) and Non Line of Sight (NLOS) targets.*

In looking at the definition, several areas of personnel expertise are suggested. The ability to fire BLOS and NLOS, for instance, suggests guided projectiles, which in turn suggests robotics and control theory, which are the areas of expertise of Mr. Krasny and Mr. Glenn, respectively. *Better sighting* suggests optics, which is Mr. Lewis' area of expertise. Other personnel were sought using the same paradigm. In addition, Mr. Ostuni effectively negated this by arbitrarily assigning people and topic areas to groups.

The individual group moderators (suggested by JSSAP) also had varying approaches to their assignments which yielded different dynamics. One moderator had a very rigid approach, taking his group along a very rigid path from the beginning of discussions, albeit along the suggested lines of discussions. Another moderator was less rigid, however, he did …*take his group down a rat hole* as one participant put it by also guiding his group along very specific topics that were distant from the more generic JSSAP topic areas.

Finally, the attitude of several of the participants could be described as neutral, based on casual conversation recorded before the sessions started. Part of this may have been inexperience with the overall moderation of the group by Mr. Ostuni, since several members seemed confused over his methods. The effects of this neutral attitude are hard to ascertain. Certainly some of the discussions were spirited, which is a desired outcome, but whether or not this suppressed creativity is unknown.

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